HOW TO READ TELEPHONE CIRCUIT DIAGRAMS

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PREFACE

Can you read the blue print?

The question comes sooner or later to every telephone employee, from messenger boy to general manager. Particularly is it necessary that trouble men and switchboard men be able to "read the blue print" of their own apparatus and to understand the principles of such diagrams, that they may be able to take up quickly the "new circuit" which always hangs over their heads.

An ability to read the little figures which dot the pages of the technical magazines is a necessity. A casual look at the simple diagrams of this volume, with their explanations, will render clear the slightly more complex ones of the magazines, and a little study will solve the complete diagrams of switchboards and other apparatus.

In the preparation of the symbols to be presented, the author has been liberal in the matter of numbers, showing such an array of typical symbols and typical variations as will enable the student of circuit diagrams to decipher any erratic symbols which may be encountered.

While the intent of the book, both in title and in the spirit of the text, is to teach the reading rather than the making of telephone circuit diagrams, yet the one cannot be taught without the other.

Often the author has been asked, "Where can I get information about how to read these circuits?" This book is the answer.

DAVID S. HULFISH.

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CONTENTS.

LESSON I.

INTRODUCTORY. CLASSES OF DIAGRAMS. WIRING AND SKELETON DIAGRAMS.

All of our written languages began with picture writing. The earlier languages gradually transformed those pictures into symbols more easily and therefore more quickly written.

The transformation came principally through the hurry or laziness of the writing person, who continually would simplify the more complex forms of symbols or pictures in an effort to accomplish a result in a minimum time or with an expenditure of a minimum amount of labor.

Coincident with these simplifications from the standpoint of the writing person came a benefit to the reading person, since the simpler symbols were as easily read at any time, and far more easily read than the more complex ones when made with little or no care.

The telephone circuit diagram has a language all its own. That this language is worthy of consideration as a language in itself is a statement quite in harmony with the history of the development of the language of diagrams, when studied comparatively with the history of the different written languages of the peoples of the earth.

It is a simple language when approached in a spirit of reverence. It is quickly mastered when in-

telligently and painstakingly studied. To him, however, who rushes unprepared into the task of deciphering an intricate circuit drawing, the barbed wire entanglements of a military defense thereafter need have no terrors.

Confusion to the reader of a circuit diagram may result from lack of skill on the part of the maker of the diagram. Such a lack of skill will be disclosed most likely and most noticeably by the use of new and eccentric symbols for apparatus parts instead of generally accepted and widely known symbols. One unfamiliar with the accepted symbols may originate a symbol so unlike anything theretofore used that his symbol appears at first unintelligible. In such a case the meaning of the various unusual symbols, and of the complete diagram, may be deciphered by the exercise of a knowledge of the principles through which the accepted symbols have been developed.

The student will be helped by observing the general rule that each symbol used in the telephone circuit diagrams of the present day was originally a picture of the unit of apparatus represented, or of a vital or distinctive part thereof. This is not a rule to be taken without exception, but it is almost universally true for symbols representing detached units of apparatus. The modifications which have been placed upon these original pictures sometimes so obscure the original as almost to take away its identity, and the different viewpoints which may be taken for a single unit of apparatus sometimes lead to confusion.

The rule may be recited, that a symbol is a picture simplified to make it easier to write or draw.

Acquaintance with the mechanism itself is of value in reading the symbols of a telephone circuit diagram. An acquaintance with the principle of operation is necessary, and knowledge of detailed construction may be required in some instances. Any specialization of construction of a standard part of apparatus usually is indicated in some way in the diagram, or the variation is explained by supplementary illustration or text.

The general rule for making a telephone circuit diagram is to locate upon the page a symbol for each of the units of apparatus, and then to connect the conductors, or certain terminals of those symbols by drawing lines to represent conductors or wires. The location of the symbols upon the page is in general immaterial, since the electrical relation usually is shown rather than the mechanical relation; this, however leads to a subject for later consideration, viz.: the combination of mechanical details with the electrical details of a circuit diagram. See Fig. 549 and its lesson.

Those telephone circuit diagrams which are confined substantially to electrical details may be divided into two classes. The basis of division is the purpose for which they are to be used.

First for consideration is that class of circuit diagrams known as "wiring diagrams." Diagrams of this class are intended primarily for use in enabling workmen to connect the electrical circuit wires running

between the different parts when the telephone system or apparatus is being constructed. In such a diagram the various mechanical parts necessarily are shown in sufficient detail to enable the workman to identify the different terminals of each part upon the part itself, by reference to the wiring diagram; the workman then proceeds to connect the indicated terminals by circuit wires as shown in the wiring diagram, thus completing the structure. Such diagrams usually show each of the parts of apparatus in such degree of detail as to enable the operation of each part to be noted. Thus the entire circuits of the structure may be learned from the wiring diagram and the structure as a whole may be understood from it.

In addition to service for the construction of the telephone apparatus, and for connecting the apparatus together to form a complete telephone system or exchange, the wiring diagram is a necessity in the operation and maintenance of the apparatus, enabling faults to be located and repairs to be made with facility.

It would seem that the wiring diagram fulfills all of the requirements of any telephone circuit diagram so far as electrical conditions are concerned, since it enables the apparatus to be constructed, maintained and understood thoroughly. Its single fault is that it is complex. For this reason alone a second class of circuit diagrams exists.

The second class comprises simplified circuit diagrams. These are known as "simplified," "schematic," "theoretical" or "skeleton" diagrams. They set forth the electrical details or relations only, and show those

as simply as possible. In the symbols the greatest simplification is desirable, and the lines connecting the various parts are to be interpreted as representing electrical conductors rather than wires in any part of the system. A single line upon a "schematic" diagram may correspond to several wires in the wiring diagram and in the physical apparatus, or merely to a conducting structural part in the apparatus. The object of the skeleton diagram is to offer a synopsis of the detailed wiring diagram in order that the nature of the system, its object and its means of accomplishing that object may be grasped readily by a reader to whom the entire subject matter of the circuit is new. The skeleton circuit therefore offers a condensed and easily read synopsis of the complete circuit, and for most purposes is preferable to the more complex diagram. In addition, it offers a key to the more complex diagram and enables it to be more quickly and intelligently studied.

It is customary to accompany a complex detailed circuit or wiring diagram by a small skeleton diagram of the same subject. Fig. 549 shows wiring and skeleton diagrams having this relation. In many instances a study of the small diagram will be found sufficient for the reader's purpose, and if it is not so, then that particular portion of the detailed diagram involved may be studied.

A very good conception of the relation of the two types of diagrams when thus used jointly is to regard the detailed diagram as a mass of information to which the skeleton diagram is the index or key.

LESSON II.

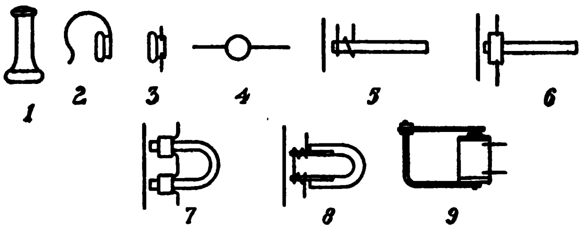
SYMBOLS. THE TELEPHONE RECEIVER. BATTERIES. A SIMPLE CIRCUIT. TRANSMITTERS.

The first requirement of the reader of telephone circuit diagrams is the ability to recognize the more common parts of apparatus by their symbols. For the acquirement of skill by the student in this direction the more common pieces of telephone apparatus will be taken up in order.

The telephone receiver as used by the public at the present day appears in containing cases of distinctive types, and pictorial representations of typical receiver cases are widely used as symbols for receivers. The types most commonly used are those of Fig. 1 and Fig. 2. When Fig 1 is supplied with surface shading it becomes a picture; without the shading it is merely a symbol of a type of receiver usually used at substation telephones. Fig. 2 represents an operator's receiver, with head band. Fig. 3 also represents the operator's receiver, or "watch case" receiver, but without the head band. Fig. 4 represents a face view of the receiver, either of the subscriber's type of Fig. 1, or the operator's type of Figs. 2 and 3. Fig. 4 is a symbol which requires "context," or the assistance of associated parts of the diagram, to enable its meaning to be determined; but when we find a simple transmitter symbol, a simple induction coil symbol and the symbol of Fig. 4, properly associated with con-

necting wires, it will be clear to the reader from the association that Fig. 4 represents a receiver, probably being intended for a face view or a rear view, although the maker of the symbol may have had the thought of picturing the receiver diaphragm alone.

The original telephone, which was used as both transmitter and receiver, comprised an electromagnet mounted on end within a cup-like wooden box and



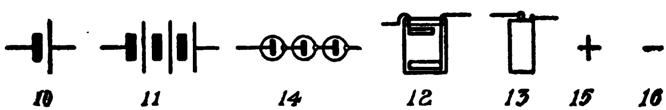
Figs. 1 to 9. Symbols for Telephone Receivers.

reaching near the top of the box. A sheet-iron diaphragm was laid over the top of the box and served at once as a diaphragm for the telephone and as a cover for the box. This device was substantially a rod of iron with a wire wound around it a few times, in combination with a disc of sheet iron held mechanically over the end of the rod, and near it but not touching it. All of the electrical features are represented or pictured in the simple diagram or symbol of Fig. 5, which is a common symbol for any receiver or magneto transmitter. In this symbol no note is taken of any mechanical detail of the piece of apparatus, its electrical features alone being noted in diagrammatic form. Fig. 6 shows a modification of the symbol of

Fig. 5, a spool of wire being shown instead of the few turns of wire shown in Fig. 5.

In the very earliest days of the telephone the device was modified to bring both poles of the magnet to bear near the diaphragm, giving the type symbolized in Fig. 7 and Fig. 8, both of which symbols are found in the early literature of the art. Fig. 8 shows a construction presumably having a permanent magnet of horseshoe form. The symbol of Fig. 9 also represents a receiver or magneto telephone, and is of interest as being the symbol used by the inventor, Alexander Graham Bell, in the first telephone patent ever issued.

In this set of symbols for the receiver, Fig. 4 should be noted as being the ultimate reduction of the pictorial idea, and Fig. 5 as being the ultimate reduction of the diagram of vital parts, both of these



Figs. 10 to 16. Electric Batteries in Symbolic Form.

symbols being reduced to a point of great simplicity and ease of drawing.

The accepted symbol for a battery cell is that shown in Fig. 10, and no symbol is more generally or uniformly used. To represent a battery of a number of cells the symbol is repeated as shown in Fig. 11, that figure representing three cells in series. The number of symbols thus written into one battery need not correspond to the exact number of cells intended

to be represented, hence the voltage of a battery cannot be estimated by the symbol alone. This follows also because the symbol (Fig. 10) is used for any type of battery, while the potential of the different types of batteries vary, a gravity cell being about one volt, a dry cell about one and one-half volts and a storage cell about two volts. The symbol for a battery therefore does not determine the potential definitely, but where two batteries, which necessarily are different in potential, are included in the same diagram the higher potential should be shown by a greater number of symbols than the lower, thus disclosing the relative potentials of the two.

Other battery symbols are shown in Fig. 12, which represents a gravity cell; Fig. 13, which represents the side of a dry cell, and Fig. 14, which represents a top view of three dry cells connected. These symbols are rare, but may be taken as types of exceptions.

The polarity of the terminals of a battery in a symbol where the polarity is not marked is a point not decided by custom. A few manufacturers and operating telephone companies have adopted a rule for their own use, but inasmuch as these standards differ, it may be said generally that no standard has been set as yet.

The origin of the battery symbol does not help in the matter of settling the question of a standard symbol expressing polarity as well as potential. The development of the symbol of Fig. 10 is not authoritatively known, but it may be assumed to have its origin in a picture. If, now, the gravity cell of Fig.

12 were taken as the prototype of Fig. 10, the shorter of the two elements of Fig. 10 would represent the shorter of the two elements of Fig. 12, namely, the upper or zinc element; this fixes the shorter element as being of negative polarity. Note, however, how closely the short element of Fig. 10 corresponds to the middle or carbon element of the cells of Fig. 14, which is the positive element of the cell; furthermore, the short element of Fig. 10 usually is made heavy and black, and carbon is black and carbon is positive; this argument tends to show the shorter element of Fig. 10 as being of positive polarity.

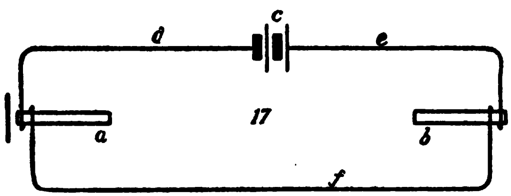


Fig. 17. A Simple Telephone Circuit Diagram.

In making a diagram the maker may determine his polarities and adhere to his own law. In reading a diagram, however, the polarities have been determined by the maker of the diagram if they have been considered at all, and the reader must accept what is set before him.

In diagrams where the polarities are essential, the polarity signs, Fig. 15 for plus or positive and Fig. 16 for minus or negative, should be set adjacent to the end elements of the row of battery symbols. The indication of the polarity of the battery is done almost

invariably in wiring diagrams, and but seldom in skeleton diagrams.

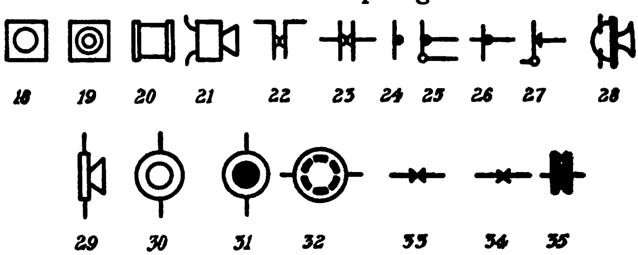
A knowledge of the diagrams thus far studied will enable the student now to read a simple circuit, such as that of Fig. 17.

For ready reference in written text to different parts of a diagram, letters or numerals may be placed upon the page adjacent to the various parts of the diagram. These are called "reference letters," "reference numerals," or "labels," and are used to identify the symbols in the text. Thus, in Fig. 17, we have the telephone *a* and the telephone *b*, connected with the battery *c* by means of wires or conductors *d*, *e* and *f*. The circuit of the diagram is read, "the circuit *c, e, b, f, a, d*." This is the original telephone circuit, the battery *c* acting through the windings of the two telephones to produce the magnetism necessary for speech transmission. The two telephones were used both as receivers and transmitters, so that the circuit shown is complete for talking purposes.

The variable resistance transmitter has its full quota of picture symbols representing the containing case of the transmitter. The earlier transmitters were inclosed in wooden boxes, and from this type of case we have the symbols of Figs. 18 and 19, representing front views of a box with a funnel-shaped opening behind which the diaphragm is mounted; also Figs. 20 and 21, which are side views of the same device. The connecting wires are run into these symbols in any way convenient when drawing the diagram of which they form a part.

The earliest type of variable resistance transmitter to come into wide use consisted of a single contact between two points, one of carbon and one of platinum. In Figs. 22 and 23 we have a symbol constituting a drawing of this vital feature of the transmitter. It is shown twice to illustrate the two methods of connecting the conductors of the diagram to the symbol, the symbol itself comprising merely two parallel lines with osculating projections.

Since the principal features of a variable resistance carbon transmitter are the diaphragm and the carbon



Figs. 18 to 85. Transmitter Symbols.

button located approximately against the center of the diaphragm, we come logically to the most generally known and most widely used of all transmitter symbols, that of Fig. 24. Conductors are led to this symbol in several ways. Fig. 25 shows the conductors connected to the carbon element and to the edge of the diaphragm, and Fig. 26 shows them connected to the two sides of the carbon element, or to the carbon element and to the center of the diaphragm. Fig. 26 is the symbol most generally used, and it is the easiest to draw. A modification is shown in Fig. 27.

Originating as picture symbols of the familiar round metal transmitter cases, Figs. 28 and 29 represent side views and Figs. 30 and 31 represent front views.

Fig. 32 is a specialized transmitter, the pictorial symbol for which is so eccentric that the context of the diagram would be necessary to identify it as a transmitter. Eccentric symbols typifying the resistance only are shown in Figs. 33, 34 and 35.

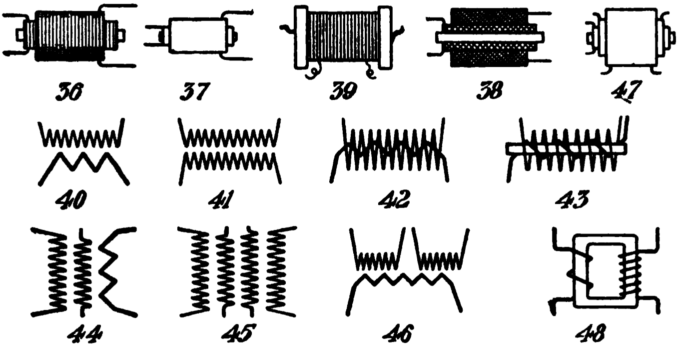
LESSON III.

INDUCTION COILS. REPEATING COILS. SWITCHHOOK AND HOOKSWITCH.

The induction coil consists of windings of two or more separate wires upon the same magnetic core. Usually, for telephone induction coils for use with the location of their respective entrances. The conductors entering at the ends or heads of the symbol shown apparently pertain to the inner or primary winding, which lies next to the core, and the conductors which enter upon the surface of the helix of wire are manifestly the secondary wires, which form the outer portion of the coil.

The induction coil is more commonly represented by showing the windings only, as in the symbols of Figs. 40, 41 and 42. In Fig. 40 an induction coil of an unequal number of turns is represented, and in Fig. 41 two windings of equal turns are typified; however, this is a matter in which the indication is not rigidly followed, and Fig. 41 is commonly used without reference to the equality or inequality of the number of turns. The use of the symbol of Fig. 40 is preferable where it properly can be used in a diagram consistently with the facts. In Figs. 40 and 41 the windings are shown separated, but near each other and parallel; this is desirable, since it makes a skeleton circuit more easily read, or, to say the least, makes it look less jumbled and confusing because of the

fewer crossed conductors. Fig. 42 shows the true relations of the two windings. Fig. 43 is a more elabo-transmitters, one of the windings is low compared with the other. This winding is next to the core, and is called the primary; the remaining winding is placed upon the first, and is called the secondary. A more efficient coil is made by winding the primary further along the core than the secondary and by making the core to project slightly beyond the primary. The



Figs. 36 to 48. Diagrammatic Induction Coils.

symbol of Fig. 36, represents a side view of such an induction coil, the symbol being shaded with surface shading to show the curvature of the surfaces. The primary and secondary conductors may be identified by noting the identity of the winding which they enter. This symbol is repeated in Fig. 37, but is not found often in diagrams without the shading. A cross sectional view of the induction coil is met frequently, the symbol appearing as shown in Fig. 38.

The symbol of Fig. 39 represents an induction coil in elevation, showing the two square heads usual upon such coils, with the surface of the helix of wire between the heads. The identity of the conductors entering this symbol may be determined sometimes by rate symbol, and shows the core upon which the conductors are wound.

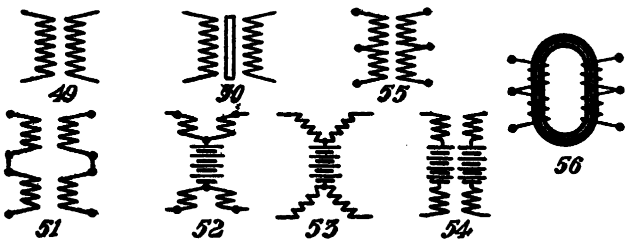
Induction coils frequently have more than two windings, in which case the additional windings are added to the symbols by amplifying the symbols without changing the principle of their construction. Figs. 44, 46 and 47 show each a primary winding with two secondary windings, or with secondary and "tertiary," as the third winding sometimes is called. Fig. 45 shows four windings inductively related, any one of which may be the "primary" so far as the symbol itself goes to show. Fig. 48 typifies the toroidal coil.

In symbols representing induction coils having windings of widely variant turns or resistances, it is customary to show the winding of the lower resistance in a heavier line in the symbol. This is really a graphic representation of the larger diameter of wire used for winding when a lower resistance is desired. Notice the symbols of Figs. 40, 42, 43, 44, and 46, as well as Fig. 39.

To pass from the consideration of induction coils to a study of repeating coils hardly changes the subject, since the repeating coil is only a specific type of induction coil, and the same general symbols apply. A repeating coil is, by its definition, an induction coil having equal windings, so that it merely "repeats"

what it receives, passing the telephonic speech currents from one of its windings to the other without changing them in any way.

The simplest symbol for the repeating coil is that of Fig. 49, which is substantially that of Fig. 41. Sometimes the core is found added, as in Fig. 50. A split repeating coil is one which has the middle points of its two windings brought to terminals accessible for the connection of external conductors. It is substantially a repeating coil or induction coil of four equal windings. Its symbol is shown in Fig. 51, the



Figs. 49 to 56. Diagrammatic Repeating Coils.

connections shown being those which are proper when the coil is to be used merely for repeating from one telephone circuit to another.

The split repeating coil is the type of coil usually used for feeding current supply from a central office battery to a connecting cord pair upon the switchboard, and when so used with one battery, its symbol combined with the battery symbol appears as in Figs. 52 and 53. In Fig. 54, the symbols are combined to represent a split repeating coil associated with two batteries, independent of each other, and each supply-

ing current independently to one of the two lines between which the repeating coil is connected.

Fig. 55 shows the usual symbol for a split repeating coil with the central points connected together. In diagrams of composite telephone and telegraph circuits, and in many trunk circuit diagrams, this connection of the split repeating coil will be found.

A symbol typifying a "closed magnetic circuit" or toroidal repeating coil is shown in Fig. 56. The symbol shown is a split repeating coil. This type of symbol, which is also essentially the symbol of the induction coil of Fig. 48 may be encountered representing repeating coils or induction coils of any arrangement of windings.

Any induction coil symbol (Figs. 36 to 48) is liable to be found representing a repeating coil in a diagram; nor can such use be considered an abuse of the symbol.

The hookswitch of the substation telephone set comprises a lever, usually horizontal, pivoted at one end, with the free end projecting and having a hook formation to take the telephone receiver. This lever with its hook end forms a part of nearly every symbol representing a hookswitch. A spring is provided in connection with the lever for drawing the hook end upward when the receiver is lifted, and the weight of the receiver draws the lever down against the spring when the receiver is hung up. This spring seldom is shown in the symbols. In association with the lever are electrical contacts, some to be opened and some to be closed as the lever rises or lowers.

The variation in the number and location of hookswitch contacts is beyond recital. They may be grouped into two classes: First, those of the hookswitches wherein the hook lever itself is one of the electrical members of the switch, or carries one of the switch members rigidly attached to it; second, those of hookswitches wherein the electrical switch is a group of switching springs complete in itself, and is merely operated by the hook lever mechanically by reason of the hook lever pushing or pulling upon one of the springs of the group. In skeleton diagrams, the nature of the hookswitch seldom is taken into account, but in wiring diagrams it necessarily must be, since it is necessary to identify the terminals of the switch by means of the diagram.

In Figs. 57 to 78 inclusive are shown some symbols for hookswitches, and it is believed that these typical symbols will serve to identify any hookswitch symbols which the student may encounter.

Figs. 57 and 58 show the symbol most generally used, and show the switchhook in its two positions. The lever itself is a conductor, and moves between two fixed contact points, one above and one below, with one of which it is in contact electrically when at rest. It will be noted that the "up" or "down" position of the hook lever is to be determined only by the electrical condition of the contacts of the switch; in each instance, the hook lever is horizontal. It is most convenient to draw the lever horizontal when a draftsman is working with a T-square upon a drawing board, hence the prevalence of the horizontal lever.

Another method of showing the position of the hookswitch is to show the relative position of the receiver, since with every such switch there is necessarily a receiver. Fig. 59 shows that the hook lever is down by reason of the receiver being hung upon it, and also by the electrical condition of its contacts, the latter being the more reliable index. Fig. 60 shows that the hook lever is up, first by the presence of the receiver in a position other than that of being hung upon the hook, and second by the electrical condition of the contacts, the later being always the more reliable index. Some draftsmen and other makers of telephone circuit diagrams get into a habit of making the substation equipments always of the same type, with the receiver on the hook all of the time, or with the receiver off of the hook all of the time, as the case may be, and in such cases recourse must be had to the only true test, viz., the electrical conditions of the contacts.

The contacts may be of any number above or below the hook lever. The hook symbolized in Fig. 61 connects its lever conductor to two others when it is in its depressed condition, and disconnects its lever conductor from them and connects it to one other when in its raised condition. In the hookswitch of Fig. 62, the switching is just reversed.

In Fig. 63 the electrical switching condition of Fig. 62 is typified, but a different relation of contact members is shown. In encountering this symbol, it is not likely that any more is intended than that some model which was before the draftsman had its con-

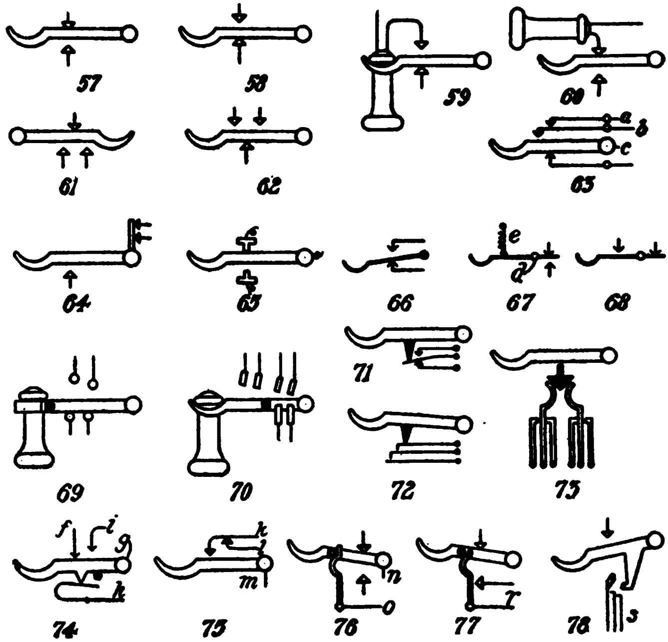
tact springs arranged in this way. However, it is possible that some peculiarity of the circuit of which this symbol is but a part may require that conductor *c* make contact electrically with conductor *b* before either *b* or *c* make contact with conductor *a*, and the symbol of Fig. 63 may have been adopted for that reason.

Do not be deceived by variations of form, such as Fig. 64, which is exactly Fig. 62, or Fig. 65, which is exactly Fig. 57. In the United States the receiver uniformly hangs at the left of the telephone set, the hook end of the switch lever being therefore at the left. The reversal of the switch lever, placing the hook at the right, usually conveys no meaning and is not a desirable variation, even if not objectionable. See Figs. 61 and 62.

Fig. 66 is Fig. 58 drawn more simply, and in which the "down" position of the hook lever is indicated by the slope of the line representing it. (Note, however, that this is confirmed by the electrical condition of the contacts, and note also that if it were not so confirmed the switch lever would be "up" regardless of its slope.)

The symbol of Fig. 67 shows a mechanical construction of hook lever in which the position of the pivot must be considered to determine which contacts are to be closed when the hook lever is up and when down. The contact shown electrically closed indicates that the hook lever is down; the spring at *e* is the tension spring to draw the hook lever up when the receiver is removed, yet in spite of the fact that the receiver is not shown in its place on the hook, and

that the spring is shown to draw the lever up when the receiver is not hung upon it, and in spite of the fact that the contact *above* the hook lever is closed and the contact *below* the lever is open, yet the hook is down because the electrical condition of the con-



Figs. 57 to 78. Telephone Hook Switch Symbols.

tacts so decide the question. This symbol is offered as an example of confusing construction which may puzzle the beginner; however, it yields to analysis and will fulfill its purpose in any circuit diagram of which

it may form a part. By moving the hook end down the electrical conditions of the contacts are not changed. By moving the hook end up the projection rearward of the pivot, *d*, and at the other end of the lever, will of course move downward, and the electrical conditions of the contacts will be changed. The hook lever, as shown, therefore, is "down."

Figs. 68, 69 and 70 are presented as characteristic of types of hook levers and switches sometimes met, and the student is given an opportunity to analyze each of them on his own account, the analysis proceeding by determining what electrical conditions would be entailed by moving the hook end of the lever up or down.

Hookswitches having contacts of the second class, are presented in Figs. 71, 72 and 73. In each of these symbols a group of switching springs is mounted adjacent to the hook lever, and some sort of mechanical engagement is provided whereby the electrical conditions of the switch contacts may be changed by the upward or downward movement of the hook lever. The student is invited to analyze each of these diagrams, also, to determine in each whether the hook lever, as shown, is up or down.

Special transient conditions of switching may be shown by the hookswitch. Such transient conditions are met frequently in telephone practice where a temporary condition for calling the central office or signaling for disconnection is made a function of central office apparatus, and the central office apparatus then is controlled by a momentary condition set up at the

substation as the hook lever passes either upward or downward.

Figs. 74 and 75 show arrangements of contact springs to give a momentary contact condition during the movement of the hook lever, which condition does not eixst after the movement of the lever is completed fully.

In Fig. 74 the conductor *h* is in connection with the hook lever *g*, and as the lever moves upward it makes connection with the contact point *f*, thus connecting *g* and *h* and *f*; this connection is but temporary, since before the hook lever reaches the limit of its movement the tip of the curved spring to which conductor *h* is connected engages the black projection (black indicates insulation), and thus the spring is held back and the downward tooth upon the hook lever is permitted to move out of engagement with the spring; this breaks the connection between *h* and *f* and terminates the temporary condition. The connection with contact *i* is made also, but seems to have nothing to do with the transient condition. Upon the downward movement of the hook lever the condition is repeated, the electrical results being the same, but the contacts being made mechanically in reverse order.

In Fig. 75 hook lever *m* engages the contact of the upper spring *k* and mechanically lifts it from the spring *l*. Of course, electrical connection between *m* and *l* through *k* exists momentarily, and this is repeated by the reversed contacting and breaking when the hook lever moves downward.

In switches of the type of Figs. 71, 72 and 73 simi-

lar conditions of the consequent making and breaking of the switch springs may be attained in a manner which will be obvious after switches of various types have been studied.

Special mechanical devices forming parts of the hookswitch, or associated with it, are shown in Figs. 76, 77 and 78. In Fig. 76 a pin projects from the hook lever and rubs against the vertical bent spring just below it, thus connecting conductors *n* and *o* when the hook is part way of its movement, the pin coming to rest either above or below the bent portion of the spring when the hook lever is at rest. All of this is indicated in the symbol, but when this symbol is a part of a complete diagram this action may be confirmed by the consideration that the circuit in which it is found requires such a condition at the hookswitch to make the other parts of the circuit diagram operative.

In Fig. 77 an insulated projection upon the hook lever presses the vertical spring to the left and against the shorter vertical contact member, thus connecting electrically the two conductors *r*, transiently.

In Fig. 78 the three conductors *s* are connected momentarily as the hook lever passes downward, but not when it passes upward. As the hook lever passes upward the vertical spring at the left is pressed away from its two companions; as the hook lever passes downward the spring at the left is pressed toward its companions.

Where no special mechanical details or require-

ments of the hook mechanism are to be shown the symbols of Figs. 59 and 60 are preferable.

Hookswitches in desk stands, where the space for the mechanism is necessarily restricted, and in intercommunicating or "house" systems, where special automatic switching conditions are to be met and cared for, and in automatic telephone exchanges, may have such conditions as call for special symbols embodying more or less of mechanism of the whole telephone set. It is likely that in every instance the symbols all can be deciphered and understood by an analysis first of the requirements of the remainder of the circuit, which must be met by the hookswitch device and by the application then of the principles of analysis gained from the study of the specimen symbols here given.

LESSON IV.

RINGERS. CONDENSERS. HAND GENERATORS.

The most common type of telephone bell or ringer consists of a permanently magnetized bar magnet and a pair of electromagnet spools mounted side by side in the magnetic field of the bar magnet; opposite the ends of the electromagnets is hung an armature, suspended at its middle point and carrying a rod and tapper ball. The tapper ball plies between two gongs. A suitable alternating ringing current passed through the two spools of the electromagnets will cause the attraction first of one end of the armature and then of the other, causing the tapper ball to strike the two gongs alternately.

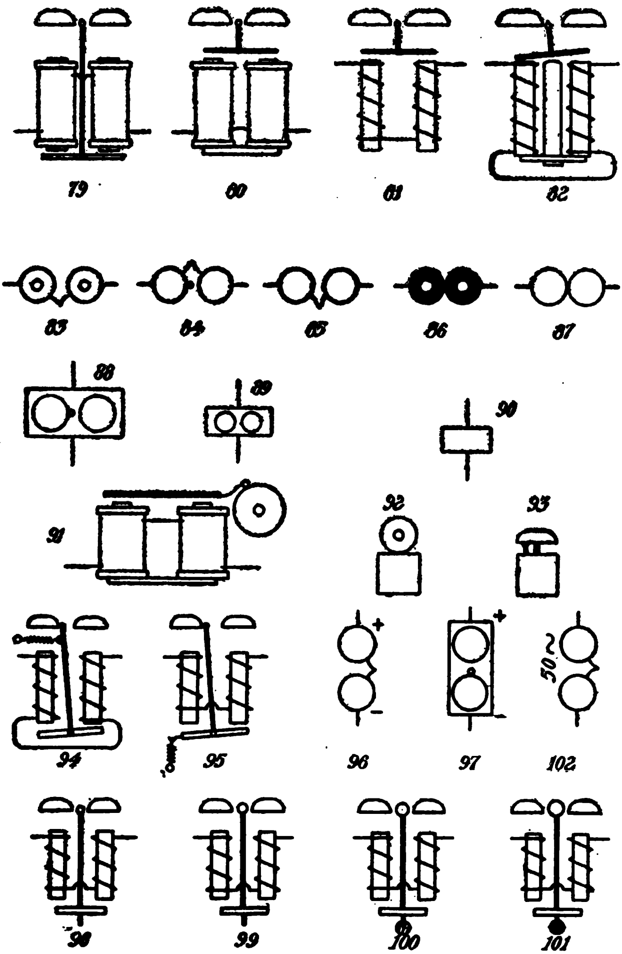
This type of telephone ringer is represented frequently by a picture more or less nearly complete, and therefore easily recognized. Such a representation hardly can be called a "symbol" until it has been reduced in simplicity to Figs. 79, 80, 81 or equivalent. In these three simple pictures the permanent bar magnet is not shown. It is added in Fig. 82, and often forms a part of the ringer symbol.

In Figs. 79, 80 and 81 the convenience of the draftsman makes the armature horizontal, whereas in all polarized ringers of the types shown the armature always will stick to one or the other of the cores, due to the influence of the permanent magnet. Compare this with the horizontal switch hook levers, and the

principle of draftsman's convenience will begin to be appreciated. Note the symbol of Fig. 82, wherein the armature is in a position which really is its position of rest. Note the lack of symmetry and judge whether the horizontal armature is not more acceptable to the eye of the reader because of its symmetry, as well as more acceptable to the draftsman because of its greater ease in drawing.

An easier view to draw is that wherein the gongs are presented to the observer. This view is taken in the symbols of Figs. 83, 84, 85, 86 and 87. Fig. 83 shows a familiar symbol, in which the large circles may be considered either as the gongs of the ringer or as a representation of the ends or heads of the magnet spools. In Fig. 84 the tapper ball is shown, fixing the circles as gongs. In Fig. 85, which is the most generally used of all ringer symbols, even the detail of tapper ball is omitted, the gongs or spool ends alone being shown. In Fig. 86 the spool heads and core ends are indicated, the spool heads being shown black to indicate insulation and surrounding the smaller circles of the core ends. In Fig. 87 the draftsman seems to have excelled himself in the matter of simplification or ease of drawing. It is possibly too simple to be good, but this objection may be urged only because it has not been adopted generally. Fig. 85 is the favorite.

A telephone ringer mounted in a box, with gongs and tapper visible upon the top thereof, is typified in Fig. 88. In Fig. 89 the size is reduced and the tapper ball is omitted. In Fig. 90 even the gongs are omitted,



Figs. 79 to 102. Telephone Ringer Symbols.

and the small square is hardly identifiable as a ringer when taken alone. When found in connection with the other elements of a substation telephone equipment, and particularly when associated with the under contact of a telephone hookswitch, or when connected across the line conductors in series with a condenser, the simple symbols of Figs. 87 and 90 are identified as representing ringers just as surely as if drawn in full detail.

In some instances eccentric arrangements of electromagnets associated with gongs or of rectangles representing inclosing boxes and associated with gongs are used to indicate telephone ringers. Typical instances are shown in Figs. 91, 92 and 93. Fig. 92 is substantially the usual symbol for a vibrating bell, such as a door bell, but, inasmuch as such a bell will respond to telephone ringing currents when the back contact is screwed up too far to permit the contact to break, the symbol is not entirely in error.

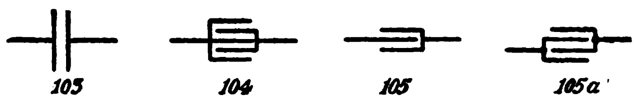
In selective ringing systems a specialized ringer is used, and this specialization may be indicated in the symbol in some instances.

The biased polarized bell is a common instance of such a ringer. This bell is an ordinary polarized telephone ringer (polarized by the presence of the permanently magnetized bar magnet) with the addition of some modification by which it acquires a "bias" or a tendency always to stick against the same gong of the pair when at rest. This bias may be applied by mounting the ringer sidewise so that the force of gravity acts in one direction only upon the tapper ball, or it

may be applied by a spring upon the armature or upon the tapper rod. See Figs. 94 and 95 for the indication of a biasing spring in a ringer. Bias is indicated also by affixing polarity signs to the ringer symbol. Thus, in Figs. 96 and 97 there is indicated a ringer which must have a positive pole of a battery or electric generator applied to its upper terminal to operate the ringer to give a signal, the ringing current flowing downward through the ringer to the remaining terminal and then returning to the battery or generator. A current flowing through the ringer of this symbol in the reverse direction is assumed not to actuate the device.

Another common type of selective ringer is the "harmonic" or "tuned" ringer. In this type of ringer the armature is suspended by a short stiff flat spring or "reed" as it is called. The most noticeable distinction between ringers of this type which are tuned to different frequencies of ringing current is the weighting of the armature, usually accomplished by a difference in the size of the tapper ball. Figs. 98, 99, 100 and 101 show a set of four such ringers. Note the tuning reed projecting from the middle of the armature. This in itself is sufficient to indicate a tuned ringer, and a difference in tuning is indicated by the sizes of the tapper balls. Another device for indicating a tuned ringer and its frequency as well is to note near it the symbol for the frequency of the current which is required to actuate the ringer. Fig. 102 indicates a tuned ringer adjusted to ring in response to a current of 50 cycles per second.

The condenser consists of two plates or surfaces, near each other but not touching each other in conducting contact. Because they are near, a charge of electricity upon one of the plates will "induce" a charge upon the other plate, and thus there is attained seemingly the paradox of a current of electricity passing where a conductor does not exist. The amount of current thus passed, however, usually is minute, but in case of alternating currents, where the total current flow is made up of small quantities of current for very short intervals and constantly changing in direction and stopping and starting again, the condenser offers a path through which the total of the



Figs. 103 to 105a. Condensers Symbolized.

small but continually repeated induced charges may amount to a serviceable current. The symbol for the condenser, therefore, may be found in conductors where alternating current is required to pass and where direct current is required to be obstructed. The symbol may be expected in any ringer circuit, or in any circuit for speech currents. Three fundamental symbols for a condenser are commonly used. Fig. 103 represents two condenser plates face to face. Fig. 104 represents a stack of plates in two systems of leaves, each leaf of each system offering both sides to the opposing system, except the outer leaves. Fig. 105 is the reduction to maximum simplicity of the

symbol of Fig. 104, and Fig. 105, perhaps, is best of the three. Fig. 105*a* is another modification of the symbol of Fig. 104. The third type of symbol for condenser is rare. It is shown in Fig. 505.

The common method of manufacture for a telephone condenser is to roll together strips of paper and tin foil; the roll thus formed may be pressed flat or used in its cylindrical form. By reason of this method of construction efforts to picture or to symbolize the rolled condenser and to indicate its rolled form are likely to be met, and Fig. 505 is one of them. Adjustable condensers are shown in Figs. 506 to 510.

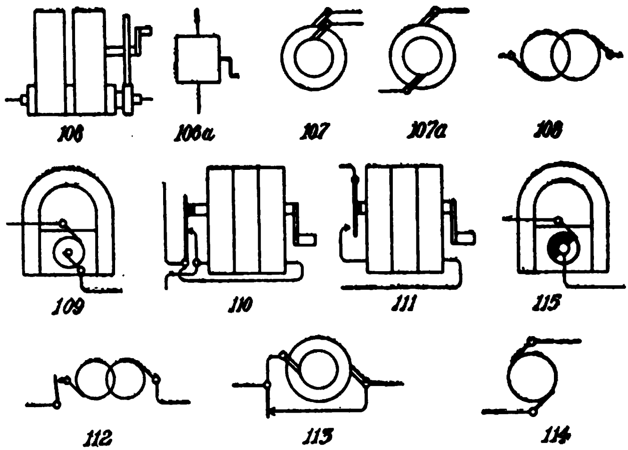
The one distinguishing feature about a hand generator, or "magneto," such as is used upon farm lines and in small exchanges and on toll lines, is the crank. Hence, with any strange looking emblem having an indication of a crank there is a great likelihood that it represents a hand generator. See Fig. 106*a* as an example.

The hand generator usually is an alternating current device. Figs. 107 and 108 are symbols for alternating current generators, whether hand driven or otherwise. An arbitrary modification of Fig. 107 is shown in Fig. 107*a*. In all of these symbols the two collector rings upon the armature shaft are indicated, and also the collector brushes which rest upon the collector rings.

Most hand generators have an automatic switch which at first effort to turn the crank is operated to switch the generator into operative relation to the telephone system, the automatic switch operating

again to switch the generator out of the circuits when the crank is released. Such a switch is shown as a part of the symbol in Figs. 110 and 111; in these symbols it may be assumed that the operator must push in upon the crank while turning.

Fig. 106 is a symbol taken from the "Chart for Draftsmen" of the United States Patent Office. This



Figs. 106 to 115. Hand Generators Shown Diagrammatically.

represents a simplified side view of a magneto hand generator without an automatic switch. Fig. 109 shows a simplified end view of a magneto generator for alternating currents. It embodies a combination of the horseshoe magnets of the generator with the symbol of Figs. 107 and 107*a* for the armature details.

In Figs. 112 and 113 the electrical switches shown

in connection with the symbols for alternating current generators indicate the contacts of the automatic switch forming a part of the hand generator. In the generator symbolized in Fig. 112, the armature circuit is open when the crank is not being turned. In the generator of Fig. 113, the armature is shortcircuited when the crank is not being turned. Symbols 111 and 112 therefore represent generators electrically the same; symbols 110 and 113 also represent generators electrically the same. In the instances of Figs. 110 and 111, the mechanical appearance of each of the devices is catered to, while in Figs. 112 and 113 only the electrical functions of the devices are brought to notice.

Fig. 114 is the accepted symbol for a direct-current generator, whether hand or power driven.

The symbol of Fig. 114 frequently is used carelessly, being somewhat easier to draw than any symbol for alternating current generator, and it is likely to be found representing any kind of a generator anywhere, even a hand generator at a substation telephone.

A "pulsating" magneto generator is typified in Fig. 115. In such a generator, one half of the alternating current is suppressed by making one half of the collecting ring of insulating material, thus converting the collector ring into a commutator. Such a generator gives a current consisting of "pulsations" of current always of the same polarity, or flowing always in the same direction, but with intervals of no current between them where the other half of the alternating

current is suppressed. Such a current is not a continuous direct current, but is a current suitable for ringing a biased polarized bell, such as those represented by the symbols of Figs. 94, 95, 96 and 97. The plus and minus signs may be added to the generator to indicate the polarity or direction of the pulsations.

Inasmuch as these hand magnetos seldom are continuous or direct current devices, the presence of simple polarity marks near an alterating current symbol would indicate that pulsating current and not alternating current is to be delivered.

Symbols for pulsating magnetos may be expected in connection with biased polarized ringers, particularly on party lines. Combinations of these elements sometimes are made to permit selective signaling from the substations to the central office, as well as vice versa.

LESSON V.

SUBSTATION CIRCUITS.

All of the elements going to make up the usual substation telephone equipments now have been studied and their symbols presented. In combining the elements required for a telephone equipment, to produce a skeleton diagram of the circuit of the telephone set, the symbols of the separate elements are drawn upon the page, and are connected by lines representing the wires or electrical conductors of the equipment. The several telephone sets thus drawn in skeleton then may be connected with each other or with central office apparatus by lines representing the line wires of the telephone lines.

Some simple telephone lines with the station circuits in skeleton diagram form will be presented and studied, that the student may become familiar with the methods of assembling symbols into a circuit or system diagram, before the more complex diagrams involving switchboard circuits and details are taken up.

In Fig. 116 is shown a simple common battery circuit for a private line, without signaling devices, but with transmitters and receivers. The receiver is numbered *1*, the transmitter *26*, and the hook lever *58*. These numbers are the numbers of the figures in which those symbols were presented separately, and they also will

serve to identify the parts of the diagram when referring to them in the text.

Fig. 116 presents a very simple form of circuit for studying permutations of circuit conditions. Only four permutations exist. First, with the receiver at station *A* off the hook, the circuit between the two line wires is closed at that station, but open at station *B*. Second, with the receiver at station *B* off the hook and with the receiver at station *A* on the hook, the circuit between the two line wires is closed at station *B* but open at station *A*. This is a condition of one

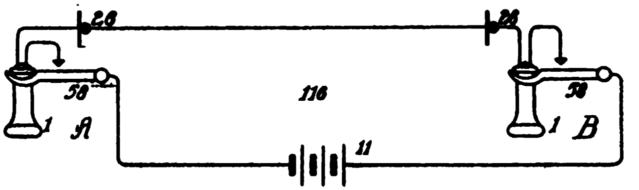


Fig. 116. Common Battery Talking Circuit.

station waiting for the other station to answer, and during the continuance of either condition there is no current flowing from the battery *11*, and no possibility of speech transmission, since a circuit for current of any kind does not exist. The third condition is when both of the receivers are off the hooks. This closes a circuit for current from the battery *11*. Note that current may flow from battery *11*, to the right to station *B*, upward and through the closed contact of the hookswitch *58* of station *B*, then through the receiver *1* of station *B*, which receiver of course will be off of the hook, then up and to the left through the trans-

mitter *26;* then to the left over the line wire to the transmitter *26* of station *A,* then downward and through the receiver *1* and closed contact of the hook-switch *58* of station *A* and down and to the right over the line wire to the battery *11,* thus completing a circuit. Current will flow over this circuit continuously until the circuit is broken, and the only places it may be broken are found at the two hook-switches, and presumably only by the hanging of one of the receivers upon its hook.

The fourth condition of circuit permutation in Fig. 116 is that in which both of the receivers are upon their hooks, the circuit then being broken in both places. This condition is the state of rest, and is the condition shown in the diagram.

Most circuit diagrams show the apparatus in a condition of rest or idleness, and the various possible, probable or intended conditions of service are left for the reader to solve by a "cut and try" process, in which all of the possible changes are taken into consideration, or are tried until the proper one or at least a reasonable one is found.

Returning to a consideration of the active condition of Fig. 116, in which both of the receivers are off of the hooks, and a circuit for current from battery *11* exists, it will be seen that any variation in the resistance of either of the transmitters will cause variations of the current from the battery *11,* and this varying current passes through both of the receivers at the two stations, so that speech in either transmitter will be heard in both of the receivers. Thus speech

may be transmitted from one to the other of the two stations, *A* and *B*, but no provision for signals of any kind other than speech signals is provided.

In Fig. 117, signaling means are added to the circuit of Fig. 116; otherwise, the circuit is the same. Here the permutations are greater in number. Signaling conditions are offered for either station *A* to call station *B* or for station *B* to call station *A*.

Assume that station *A* desires to call station *B*. The telephone user at station *A* turns his hand generator, *112*, generating alternating current and closing

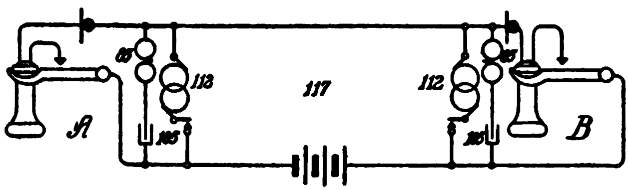


Fig. 117. Common Battery Talking and Magneto Signaling Circuit.

the automatic switch shown open, which is its normal position of idleness, and which is a part of the hand generator *112*. Alternating current will flow from the generator *112* downward to the lower line conductor and upward to the upper line conductor, and will find two paths between the two line conductors, forming two complete circuits for current.

The nature of the condensers, *105* of station A and *105* of station *B*, must be considered; they will pass the alternating current, but will not pass the direct current which the battery *11* is able to give.

Alternating current flows, therefore, from *112*

through the closed automatic switch down to the lower line wire, to the left, up through condenser *105* and ringer *85* of station *A*, to the right and downward to the generator *112*. This rings the ringer *85* of station *A*. Alternating current flows also from *112* down to the lower line wire and to the right, through the battery *11* to station *B*, up through condenser *105* and ringer *85* of station *B*, ringing the ringer *85* of station *B*. This current cannot flow up through generator *112* of station *B* because the automatic switch is open when that generator is at rest; neither can the current flow up through the hookswitch *58* and receiver and transmitter of station *B*, because the receiver is upon the hook, and the hookswitch contact is open.

Both bells ring when the generator *112* at station *A* is turned. The ringing of the bell at station *A* assures the user of the telephone there that his telephone set is working properly, and that, so far as he is able, he has rung the bell at the distant station, *B*.

The telephone user at station *A* now must await the answer of some person at station *B*, listening meanwhile for the answer by holding the receiver at his ear. The removal of the receiver from the hook closes the hookswitch automatically (for this reason the gravity operated hookswitch in early days was called an "automatic hookswitch") and the talking circuit is ready to be closed automatically when the telephone user at station *B* takes his receiver from the hook to place it in position at his ear for conversation in answer to the ringing of his call bell. Such

answering on the part of the station *B* sets up exactly the same conditions as were studied in Fig. 116.

The normal conditions for which the circuit of Fig. 117 is intended now have been studied, since a study of a call by station *A* for station *B* would be just the same when *B* calls *A* except that the drawing would be read in a left-handed direction, as it were. There are abnormal conditions, however, which are worthy of note. Suppose that the telephone user at station *A*, weary of waiting for station *B* to answer, desired to ring station *B* again, and turned the crank of the generator *112* of station *A* without first replacing his receiver upon the hook, or without depressing the hook lever, then current would flow from the lower line wire up through the hookswitch, receiver and transmitter of station *A*, and would "ring in the ear" of the user. Also, the user at *A* may ring into the receiver of station *B* while it is in use, or in case it should be left off of the hook by intent or neglect. These are abnormal conditions. Another abnormal condition is the turning of both generators at the same time.

The consideration of abnormal conditions has its principal use in the matter of testing out a circuit informally to detect faults; such consideration is necessary also in studying a new circuit, to determine whether there are any abnormal conditions which are at all likely to occur which would make the line or the system inoperative.

A line having local battery transmission of speech is shown in Fig. 118, with two stations *A* and *B*. A

further difference from the circuit of Fig. 117 is the arrangement of generator and signal bell, the arrangement of Fig. 118 being for what is known as "series" ringing.

In studying first the signaling elements of the line, a call from *A* to *B* will be assumed. User at *A* turns the crank of his hand generator, which not only generates an alternating current, but also operates and opens the automatic switch shown as a part of the generator. Current flows from the generator of station *A* upward, through the ringer of station *A*, to

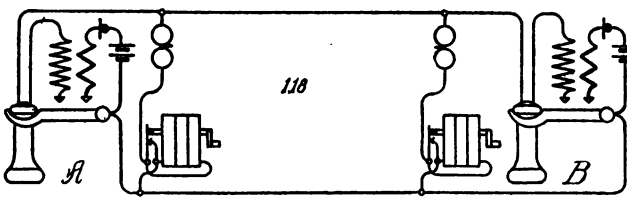


Fig. 118. Local Battery Circuit.

the top wire of the line, and has but one closed path, which is across the top line wire to station *B* and down through the ringer of station *B* and through the closed automatic switch of the generator of station *B*, thence to the left along the lower line wire and up to the generator of station *A*. The current must pass through both of the ringers, as was true also with the circuit of Fig. 117, and both bells are rung. This difference, however, will be noted: In Fig. 118 the current passes through one of the bells and then through the other, all of the current passing through both of the bells serially, whereas in Fig. 117 the cur-

rent passes through both bells at once and independently, the current which passed through one bell not passing through the other. The arrangement of Fig. 118 is called "series ringing" and that of Fig. 117 is called "multiple ringing" or "bridging ringing." Each system has advantages.

Passing from the normal conditions of ringing to normal conditions of talking in Fig. 118, the user at station *A* takes his receiver from the hook to listen for the response of station *B*. The contacts of the hookswitch of station *A* are closed.

A primary circuit thus is closed at station *A*, comprising the battery, the transmitter, the primary or heavy wire of the induction coil, one of the contacts of the hookswitch, the body of the hook lever, and the connecting wiring. A continuous current flows in this primary circuit, generated by the battery, and when the transmitter is spoken into an alternating potential is created in the secondary of the induction coil.

After station *B* has answered, a circuit for the secondary winding of the induction coil will be formed, as follows: From the secondary of the induction coil of *A* through the receiver of *A* to the upper line wire, thence to the right to station *B*, thence through the receiver and secondary of the induction coil of *B*, through the closed contact and hook lever of the hookswitch at *B*, returning over the lower line wire and upward through the closed hookswitch of *A* to the secondary winding of the induction coil, completing the circuit. The same secondary circuit is used when

the transmitter at *B* is spoken into and the receiver at *B* is off the hook. Thus either transmitter causes an alternating current to flow over both of the line wires and through both of the receivers. The speaker talks to his own ear as well as to the ear of the distant hearer.

Looking for abnormal conditions, note that a receiver left off of the hook will permit the battery to give current all of the time, which would deteriorate the battery quickly; this is not true of Fig. 116 or Fig. 117 unless both receivers are off. Other points may be noted.

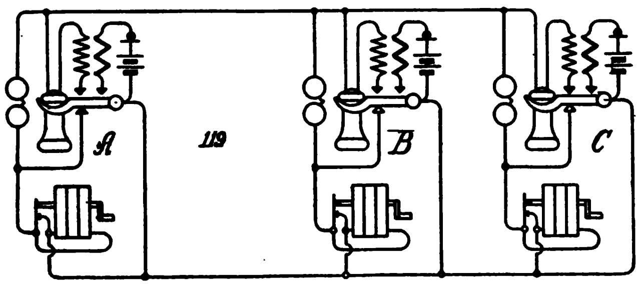


Fig. 119. Party Line Circuit.

A circuit which has been specialized for party-line conditions is shown in Fig. 119. This circuit may be studied particularly as an exercise in permutation reading of circuit diagrams.

The sole difference between a telephone set of Fig. 118 and a telephone set of Fig. 119 is in the connection extending from the middle of the ringing bridge to the under contact of the switchhook. The only

difference further is that there are three stations in the system of Fig. 119, whereas there are but two stations in Fig. 118.

The experienced reader of circuit diagrams will take his cue at once. This circuit shows two variations from the normal. Perhaps one of those variations is the cause for the other.

Beginning the study of the diagram by permutations, it is noted first that all of the apparatus of the diagram is shown in the position of rest. The hookswitches show the receivers hung up; the ringing bridges are clear with the ringers from wire to wire of the line conductors, ready to receive signals.

As a first change, assume that *A* calls one of the other stations, say *B*. The user of the telephone at *A* turns the generator crank, generating alternating current, which flows upward to the junction point between the generator and the ringer, thence to the right to the hookswitch contact, thence through the closed contact to the body of the hook lever, to the right and downward and to the left and again upward to the generator, without passing through any apparatus of any appreciable resistance, and without having had to pass through any ringer. Other paths exist, as may be traced from the generator upward through the ringer of *A* to the right and downward through the ringer of *B* and to the left to *A* again, but this latter path contains the resistance of two ringers. According to Ohm's law, the path of less resistance will take the greater current, and a path of substantially no resistance will take substantially all

of the current. The little path from the generator over to the hookswitch will take all of the current that the generator will give until that little path is broken, which can be done only by raising the receiver from the hook.

In short, the generator of station *A* is short-circuited as long as the hook lever is down. The user of the telephone at *A* cannot ring anybody's bell until after he has taken his receiver from the hook. At a glance, it is seen that the other stations are the same.

This seemingly strange limitation in the use of the apparatus for signaling may possibly have some explanation in the further permutations or changes which can be obtained upon the system. This is found in the condition where stations *B* and *C* are talking together, and *A* desires to call one of them. If *A* should ring upon the line, it would interrupt the conversation, and ring disagreeably in the receivers of stations *B* and *C*. But by the limiting condition of having his generator normally short-circuited, the user at station *A* is compelled to lift his receiver from the hook, and therefore probably will listen upon the line before turning his crank, and, finding the line already in use, probably will not turn his crank at all, and thus will not annoy the conversation between *B* and *C*.

Still another example for reading is given in Fig. 120, wherein a party line of three stations is represented. Biased bells and pulsating generators are indicated by the polarity marks adjacent to the symbols for ringers and generators. Taking the direction of current as proceeding from plus sign to minus sign,

pulsating current suitable for ringing biased bells will flow from the plus side of any of the generators, out upon the line and through such circuits as can be found, returning to the minus side of the same generator. In the matter of the ringers, current is free to flow through the ringer in either direction, but the armature will respond and the ringer will be rung only when the current comes in at the terminal marked plus and leaves the ringer at the terminal marked minus.

In Fig. 120, when station *A* rings, closing the

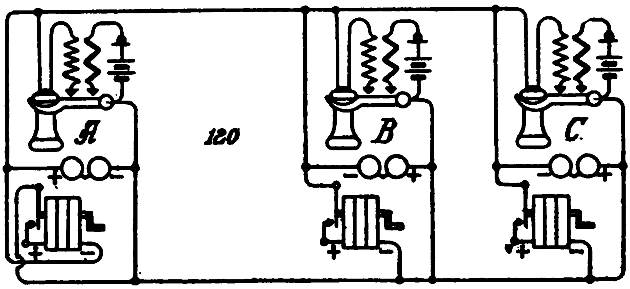


Fig. 120. Selective Party Line Circuit.

automatic switch of his hand generator and giving pulsating current, the current flows up through the automatic switch to the top of the generator symbol, thence over the conductor to the left and downward and again to the right upon the line wire at the bottom of the diagram. Three return paths, through the three ringers of the three stations, are found.

First path: At station *A*, upward from the lower line wire to the ringer connection, to the left through

the ringer, entering at the side marked minus and leaving at the side marked plus, then downward to the minus side of the generator. This does not ring the ringer of station *A* because the current entered at the minus and left the ringer at the plus sign, thus passing through it in the wrong direction.

Second path: At station *B*, upward from the lower line wire to the ringer connection, to the left through the ringer, entering at the side marked plus and leaving at the side marked minus, then upward to the upper line wire, then to the left to station *A* and to the minus terminal of the generator of station *A*. The ringer of station *B* is rung, because the current passed through it in the direction indicated by polarity signs at the ringer.

Third path: At station *C*, upward to the ringer bridge and to the left through the ringer, and upward to the upper line wire, thence to the left to station *A*. The ringer of station *C* also is rung, because the current passed through it in the proper direction, entering at the plus sign and leaving it at the minus sign.

The study thus far tells us that station *A* is unable to ring its own bell but is able to ring the bells of both station *B* and *C*.

When station *B* rings, pulsating current flows from the generator upward to the top line wire and thence to the left to station *A*, thence downward to the ringer connection, to the right through the ringer, entering the ringer by the conductor at the plus sign and leaving it by the conductor at the minus sign,

thence passing downward to the bottom line wire and to the right and upward at station *B* to the minus terminal of the generator to complete the circuit. The ringer of station *A* is rung therefore by the generator of station *B*.

A path for the ringing current from the generator of station *B* exists also through the ringer of station *B*, passing from the left of the generator, up to the ringer connection, to the right through the ringer, entering at the minus sign and leaving at the plus sign, thence downward, to the left and upward again to the minus terminal of the generator. This does not ring the ringer of station *B* because the current passed through it in the wrong direction, or the reverse direction from that indicated by the polarity signs. Station *B* therefore cannot ring its own ringer.

Another path from generator of station *B* is found through the ringer of station *C*, passing from the generator of station *B* upward to the top line wire, to the right to station *C*, downward to the ringer connection, to the right through the ringer, entering the ringer at the minus sign and leaving it at the plus sign, and not ringing it. Station *B* therefore cannot ring station *C*.

By a separate study, exactly similar to the last, but in which the generator of station *C* may be taken as a starting point instead of that of station *B*, it may be determined that station *C* is able to ring the bell of station *A* but is unable to ring either its own bell or that of station *B*.

To recapitulate for Fig. 120: Station *A* may call

station *B* or station *C;* station *B* may call station *A,* but *B* cannot call *C;* station *C* may call station *A,* but *C* cannot call *B.*

When a circuit diagram is accompanied by a statement of its purpose, its application, or the work which it is intended to do, it may be studied briefly and directly to the point, to determine whether or not it does that which is announced for it. When a circuit is given without announcement of its uses or purposes, it is necessary to read "by permutation," as the term has been defined above, studying all possible combinations of the parts of apparatus shown, to determine all of its possibilities. Such a study should not be called complete until some interpretation of the circuit has been found which fits it for a place in the known practice of telephony, or which accomplishes some new and useful result.

To confirm the study of the circuit of Fig. 120, it may be fitted to the present practice of telephony in two ways. First, the line may be a party line, with the station *A* the central office, so that either of the stations *B* or *C,* may call the central office without announcing the call to the other station of the line. This is called "silent signaling" and is a desirable feature in party-line operation. Second, the line may be a toll line owned by a party at station *A.* In this case, *A, B* and *C* would be in separate towns. When *B* calls *A* a toll charge is made for the use of the line; when *C* calls *A,* a charge is made similarly, and the same when *A* calls either *B* or *C.* But in case *B* desires to talk to *C,* a charge should be made, yet the owner of

the line is doing his bookkeeping at *A;* therefore he has arranged the line so that *B* cannot call *C,* nor vice versa, but *B* must call *A* and ask *A* to call *C.* Thus a call cannot be made without the knowledge of station *A,* and this knowledge on the part of that station enables the owner of the line always to make a charge for any conversation between station *B* and station *C.*

LESSON VI.

SWITCHBOARD CIRCUITS AND SYMBOLS.

The reading of the more complex switchboard circuit diagrams must be preceded by a study of the principal symbols used. A thorough knowledge of symbols is desirable to assist in the interpretation of unusual symbols which may be met, and some knowledge of switchboard principles and construction is necessary to enable the reader to interpret the circuits and to understand them at all.

For a preliminary understanding of the symbols and of switchboard principles, a short study of circuit diagrams representing the simplest types of switchboards will be made. An introduction to switchboards and apparatus parts by a study of a set of the simplest of the symbols used to represent the parts, followed by the exercise of reading a few simple circuits embodying the principles of switchboard operation, will prepare the student for a thorough understanding of the symbols and of the circuit methods of the more complete and more complex diagrams.

A telephone switchboard consists fundamentally of two parts, comprising respectively, two classes of apparatus. First, there are the line terminals. Second, there are the devices for connecting together the terminals of the lines. All other apparatus is auxiliary to these two fundamental divisions of the switchboard devices, and may be considered after these two classes of apparatus are understood.

In a small switchboard, each line has one terminal; in a large switchboard it may have many. Because of the multiplicity of terminals for each of the telephone lines, a large switchboard having such line equipment is called a multiple switchboard. Each line terminal is equipped with a device which presents the line's electrical conductors ready for the attachment of other conductors, whereby the line may be extended electrically by attaching removable conductors when the switchboard operator desires.

The connecting apparatus, or second division of the switchboard devices, consists fundamentally of flexible electrical conductors, each conductor having at each end a device for attaching it removably to any line terminal. It will be seen that one of these flexible conductors may be taken in the hands of the operator and its two ends fastened to the line terminals and therefore to the line conductors of any two lines in the switchboard. By such an act on the part of the operator, the two lines would be connected electrically, and patrons at telephones upon the two lines might talk with each other.

As a rule it may be stated that the simpler the line equipments for each line the more complex are the connecting devices for each connection, and vice versa. Also, the smaller the switchboard, the simpler are both the line and connecting devices, and the larger the switchboard, the more complex are both.

The "size" of a telephone switchboard is measured and expressed usually not in terms of feet and inches, but in terms of the number of telephone lines for which

terminals are provided upon the board. The method is modified sometimes to an expression of the number of telephone substations which the switchboard will serve. This distinction sometimes makes an important difference when party lines are considered. By putting more than one telephone upon a line, and by providing additional connecting apparatus to handle the additional traffic, the number of telephone stations handled by a switchboard may be increased without increasing the number of lines terminating upon the board.

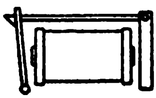
So far as talking is concerned, the above considerations cover a simple switchboard. In addition to talking facilities there must be signaling means, both to enable the subscribers of the exchange to signal the operator (to "call" the "central" office) and to enable the central office operator to signal the subscribers, that is, to ring their bells.

Taking the line terminals first, the simplest switchboard provides each of the lines with a small device which has a shutter or target similar to the "annunciator drops" sometimes used in hotels to locate or identify the guest room in which a calling push button has been pushed.

In a small simple switchboard serving magneto lines, each line terminates in one of these "drops" and in a connecting device called a "jack." At the other end of the line is the subscriber's telephone set. This condition may be studied by means of a diagram.

Fig. 121 shows the annunciator drop. The magnet, easily recognized by its form of spool with pro-

truding core ends, has at the right a comparatively heavy armature, pivoted at the top, from which a light finger, or "reed," extends above the top of the magnet toward the left and ends in a hook. Under the hook of the reed is positioned a light drop shutter, pivoted or hinged at the bottom, and inclined toward the left, so that it has at all times a tendency to fall. This shutter may be assumed to be non-magnetic, that the magnet core will have no effect in withholding it from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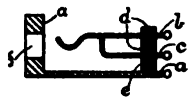

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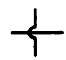
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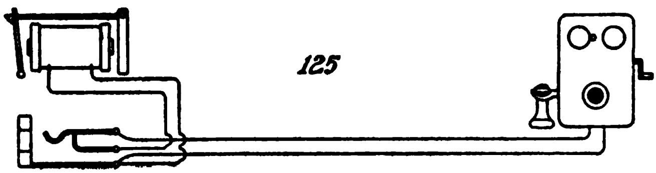
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Figs. 121 to 125. Line Circuit and Its Symbols.

falling. The operation of the device now is clear. When current flows through the wire winding of the magnet the core attracts the armature, the lower end of the armature swings to the left toward the core, and the hook end of the reed is lifted, releasing the shutter. The shutter falls by its own weight, and may be restored by the hand of the operator after the current through the magnet has ceased.

Fig. 122 shows a simple jack; not the simplest, but the kind which is used in such small magneto

switchboards as are now under discussion. In mechanical construction it consists of a cast body indicated by the letter *a*, upon which casting are mounted the movable spring *b* and the fixed contact point *c;* insulation is provided at *d* and *e* to keep the three parts electrically separate. The jack body is drilled at *f* with a hole usually one-quarter of an inch in diameter, to receive a switch plug, as will be disclosed presently.

Conducting wires are represented by simple lines, as shown in Figs. 123 and 124. In Fig. 123 the lines are represented as crossing without touching, the vertical wire jumping over the horizontal wire, if one chooses to think of it in that way. In Fig. 124 the wires are definitely joined. The small circle may be taken to represent a soldered joint between the vertical wire and the branching horizontal wire.

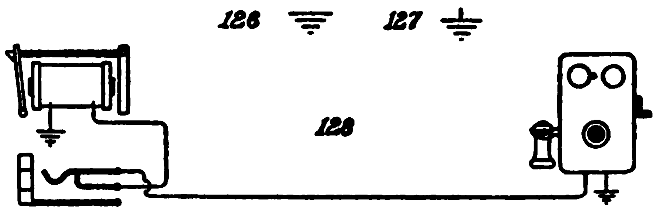
The assembled apparatus in Fig. 125 represents the complete switchboard equipment of a subscriber's line in a small magneto switchboard, together with the two wires of the line itself, and the substation telephone. The substation telephone here is symbolized, the case rather than the circuits thereof being presented. The circuits may be assumed to be those of one of the substations of Fig. 118.

By turning the crank, an alternating current is sent out over the line wires, sufficient in strength to cause the magnet of the drop to attract its armature, lifting the reed and releasing the shutter. This is called "tripping the drop" or "throwing the drop." It is seen that the drop magnet in Fig. 125 has the same

relation to the substation at the right of the figure that the ringer of the left-hand substation of Fig. 118 has to the substation at the right of Fig. 118, and that any current sent out from the substation telephone at the right of Fig. 125 must pass through the magnet of that drop, and "ring the drop down" instead of ringing the bell of a distant station.

The telephone system of Fig. 125 may be simplified by changing the diagram to show a "grounded line."

A "grounded line" is a telephone line in which



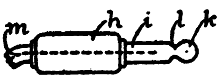
Figs. 126 to 128. Grounded-Line Circuit and Earth Symbol.

but one wire is strung on the poles, and the earth, which is a fairly good conductor under most circumstances, is used as a return path for the telephonic currents. Grounded lines are used for many farm lines, and were used exclusively for all telephone lines when the telephone was first used.

To connect the telephone in a grounded line, one wire from the central office is taken to a rod driven deep into the ground, or soldered to a water or gas pipe; at the substation, also, one wire from the telephone is similarly connected to ground; then the remaining wire from the central office equipment and

the remaining wire from the substation telephone are connected to the two ends of one line wire. The circuit is now a "grounded" circuit.

To convert the diagram of Fig. 125 into a diagram representing a grounded line, first the symbol for a ground or earth connection must be found. This is



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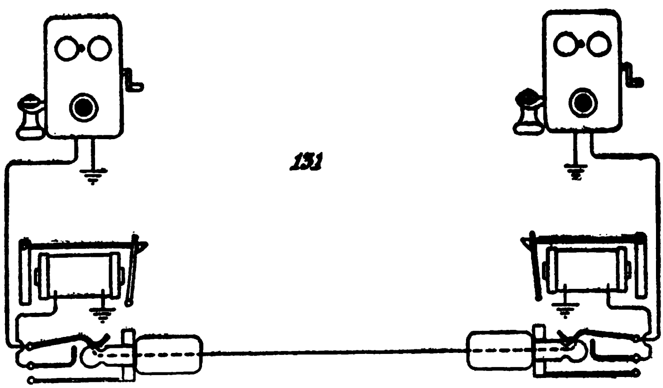


131

Figs. 129 to 131. Connecting Devices and Grounded Connection.

shown in Fig. 126, and is shown with a connected wire in Fig. 127. Applying these to Fig. 125, in the manner described above, there is produced the diagram of Fig. 128.

In Fig. 128, when the crank is turned, current flows from the substation telephone set over the line wire to the movable spring of the jack, then to the

fixed contact point of the jack, then to and through the drop magnet, then to ground or earth, thence by means cf the conductivity of the mundane sphere to the ground connection of the substation, and up the ground wire to the telephone set, completing the circuit and energizing the central office drop.

In response to the falling of the subscriber's drop, the operator must connect with his line, and must connect his line with any line desired. This is the purpose of the central office, and the reason for its existence.

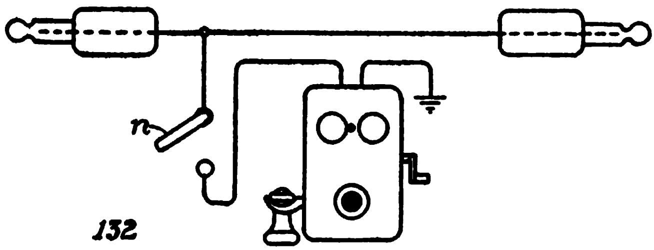
A connecting device as used by the operator consists, as has been stated, of a flexible electrical conductor having at each end a device for attaching it removably to any line terminal. The connecting device, called a "plug" or "switch plug," is shown in Fig. 129. For switching grounded lines, where but one conductor is required, the plug proper consists of a solid body of metal, usually with a shielded handle. The handle is indicated at *h*, the shaft or "body" of the plug at *i*, the tip of the plug at *k* and the reduced neck at *l*. A flexible conductor is shown at *m*, connecting through the dotted line to the metallic or conducting portion on the plug. A pair of plugs on a flexible conductor are shown in Fig. 130, and two subscriber's lines connected by a pair of plugs and a flexible cord are shown in Fig. 131. The operation of the plug of Fig. 129 when inserted in the jack of Fig. 122 is to engage and lift the movable spring away from the fixed contact point. This condition is shown in Fig. 131. The bent portion of the spring *b* of the

jack of Fig. 122 tends to hold the plug in place by taking a seat in the neck *l* of the plug, until the plug is forcibly removed by the operator.

In Fig. 130 a switching device is shown in its simplest conception, and in Fig. 131 it is shown in use. A switchboard once was built using a connecting device of this simple character, and it was a remarkably efficient switchboard, giving a service which was both prompt and reliable. Modern switching methods, however, require elaborations and refinements of apparatus which are embodied in even the most simple boards.

The first requirement for the refinement of the crudely simple device of Fig. 130 is that the operator at the central office be enabled to talk with the calling subscriber, to ask the number of the line with which he desires to be connected. This introduces the "listening key," a key or switch which permits the operator to connect her telephone with the calling line. This is accomplished by providing the little switch at *n*, shown in Fig. 132. The operator thus may talk with the calling subscriber, and may ring his bell by turning the crank of the central office telephone set. Incidentally, after both of the connecting plugs are connected with the two lines which are to engage in conversation, and in the natural order of events the bell of the telephone of the called station must be rung, the operator may ring that bell by turning the crank of the central office telephone set. With the diagram of Fig. 132 the current would divide upon the flexible conductor between the two plugs, some

current flowing out to the bell of the station to be rung, and some current flowing out to the station upon the line which had called, thus "ringing in the ear" of the calling subscriber. Another refinement now is placed in the connecting device, this one being called a "ringing key." It is shown in Fig. 133. By depress-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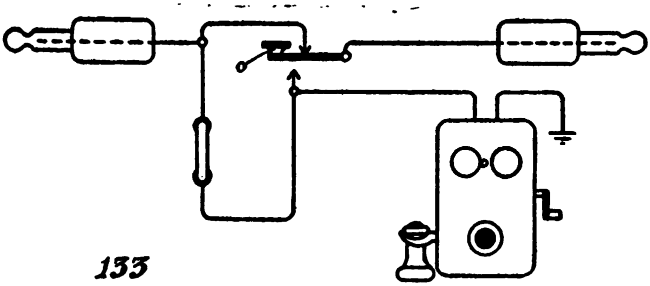

133

Figs. 132 and 133. Refinements in Connecting Devices.

ing the knob *o* after opening the listening key, the central office telephone set is connected with the station to be called without being connected with the station calling, and therefore the bell to be rung may be operated without annoying the calling subscriber.

Still another refinement is required before the con-

necting device becomes in all fundamental requirements suitable for use in the switchboard of today. The subscribers must be able to signal the central office, to call the operator, even when they are connected. For this purpose a drop is added to the connecting device, or cord-pair, as shown at *p* in Fig. 134. In case either of the subscribers connected as shown in Fig. 134 should turn the crank of his telephone set, current would flow from his generator, over the line

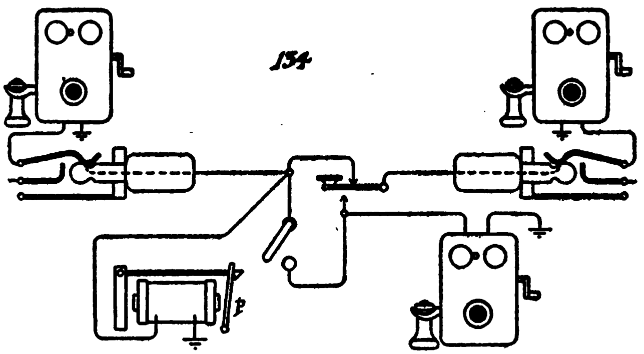


Fig. 184. Complete Connecting Device for Grounded Lines.

wire to the central office, where it would divide, some going to earth through the clearing drop and some continuing to the remaining plug and over the connected line to the other substation of the connection, actuating the ringer of that telephone set. Thus he would ring both the central office drop and the distant connected substation bell. Fig. 134 shows a complete connecting device symbolized to its greatest simplicity.

A metallic circuit connecting device, or so-called

cord-pair, is shown in diagram in Fig. 135. As compared with the "grounded circuit" line, the "metallic circuit" line has two conductors instead of one. It is the same with the cords and connecting devices and keys of the central office. The plugs must carry two conductors instead of one, an insulation separation being made between the tip and the body of the plug. The cords must carry two conductors instead of one, one of those conductors connecting to the tips of the

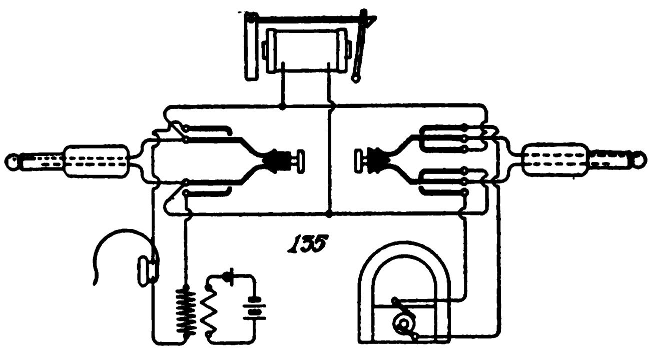


Fig. 185. Complete Connecting Device for Metallic Lines.

plugs and the other connecting to the bodies or shafts of the plugs, as shown by the dotted lines in the plugs of the figure. In the listening key there are two long springs, and two short springs or contact points with which the long springs make electrical engagement when they are bent by the black wedge of insulation, which is so arranged as to bend both of the long springs at once. In the ringing key, also, the springs are duplicated, breaking both sides of the metallic line

and connecting both sides of the right-hand plug to the central office generators. The talking equipment of the central office telephone set is shown separated from the generator in this instance, which is the custom in switchboards. The clearing drop is connected from one side of the line to the other at such a point that it does not get current from the central office generator.

Fig. 125 has shown a metallic circuit equipment for a subscriber's line. Fig. 135 shows a cord pair or connecting device suitable for connecting together two lines such as shown in Fig. 125. As an exercise in reading circuit diagrams, the student may draw two lines as shown in Fig. 125 and connect them by the device of Fig. 135. Skill in reading will be promoted by the act of drawing the suggested diagram, as well as by reading it afterward. The movable spring of the jacks must connect with the tips of the plugs, but not with the bodies of the plugs, and the movable springs are lifted from the contact points or short springs when the plugs are inserted, as shown in Fig. 134.

LESSON VII.

SUBSTATION SYMBOLS.

It does not require a deep knowledge of telephony to see that important changes in the central office equipment may be made without any changes whatever in the substation or subscriber's telephone equipments. Conversely, there may be changes in the substation equipments without changes in the central office, or even there may be many types of substation equipments, differing from each other, all working at the same time in connection with a single switchboard.

It is seen, then, that the dependence between the switchboard and the substation is not one which is very rigid, but one which pertains more to general principles or general requirements only. A magneto switchboard is a switchboard which has signal receiving devices (to enable the subscribers to signal to the operator at the switchboard) which are suitable for operation by current from a magneto or hand generator. Such a switchboard requires that the substations be provided with hand generators that they may be able to operate the central office signals, or drops. The use of the annunciator drop form of central office signal also prevents the presence of any current upon the telephone lines in any considerable quantities, since such currents would trip the drops. A magneto switchboard therefore requires that its

substations furnish their own talking current or talking energy of whatever kind, and that the substations have each a hand generator or equivalent device.

The common battery or central energy switchboard is even more lax in its requirements. Almost any kind of a substation telephone will work in connection with a common battery switchboard. The substation may have a hand generator, or not; it may have local battery transmitter or not. The only requirement of a common battery switchboard is that the line circuit be closed at the substation when the hook is up, and open to direct or battery currents when the hook is down.

The reader should bear in mind that this is a treatise on the reading of telephone circuit diagrams, and not a treatise on correct methods of telephone engineering. In correct telephone engineering, the substation equipment should be of a design in harmony with the central office or switchboard design, that a maximum efficiency for a desired character of telephonic transmission may be attained. In any circuit diagram dealing with a switchboard, the details of the substation may be assumed to be cared for by another diagram, or by other means, and for the purposes of the switchboard study it is required only that a substation telephone be indicated without a definite specification of its minor details.

A very great part of the art of the pictorial artist is exercised in subduing or in leaving out altogether the unimportant details involved in his subject. The novelist, too, omits the minor details, or treats them

lightly, briefly, suggestively. The skilled maker of telephone circuit diagrams exercises the same art, subduing the unimportant details, and for the same purpose, namely, that they may not lead the attention from the more important and the really essential features of the diagram, and that they may permit the attention of the reader to concentrate upon the important details of the diagram and thus present definitely and forcibly that portion of a telephone system which it is the purpose of that particular diagram to present.

In a diagram having to do only with the circuits of a switchboard, the minor details of the substation telephone are negligible. In most instances it is necessary only to show that the central office apparatus works in co-operation with a substation or a number of them. A need exists therefore for a symbol indicating the substation telephone as a whole without definite specification as to the details thereof, frequently neither mechanically nor electrically, it being assumed in such an instance that the substation is a proper one to co-operate with the central office equipment shown.

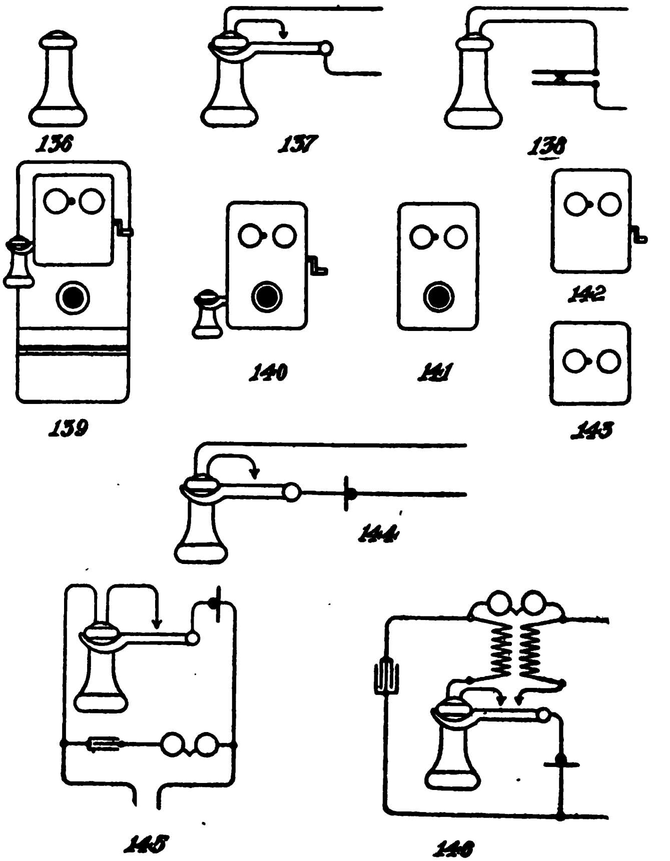
The simplest, and at the same time the most comprehensive of symbols for a complete substation telephone equipment is the symbol of Fig. 136. Merely a hand telephone. It will be recalled from earlier lessons that the telephone receiver, when equipped with a permanent magnet, may be used as a transmitter as well as receiver. When sufficiently powerful and abrupt currents are passed through the receiver,

the sound produced is loud enough to be heard in a quiet room. It is therefore not only a receiver and transmitter but a signaling device for calling the patron to the telephone. Taken in connection with a circuit showing a magneto switchboard, it is necessary to assume that the substation represented by Fig. 136 is equipped with a hand generator. In connection with a central energy circuit it is necessary to assume that a switch of some kind, presumably a hookswitch, is associated with the receiver, to open and close the line circuit through the substation to control the signals at the central office, as the central office details of the circuit diagram may require.

An amplification of the symbol of Fig. 136 is given in Fig. 137. The maker of the diagram here shown evidently was dealing with a common battery central office, and by adding the hook lever and contact all necessary details for the operation of the central office system have been provided. Such a substation equipment, comprising only receiver and hookswitch, would be very inefficient for a modern telephone plant, and therefore it must be read, not as a complete diagram showing all details of the substation, but merely as a symbol suggesting a complete substation, equipped with all that is needful or customary to co-operate fully with the central office, or other more detailed portions of the telephone system set forth in the diagram where this symbol is found.

In Fig. 138 the device adjacent to the receiver might be hookswitch contacts such as those of Fig. 71 with the hook lever not shown, or it may represent

a transmitter as indicated in Fig. 22. The meaning of the *part* of the symbol is immaterial, since it is clear that the symbol of Fig. 138 is intended to be read as



Figs. 136 to 146. Symbols for Complete Substations.

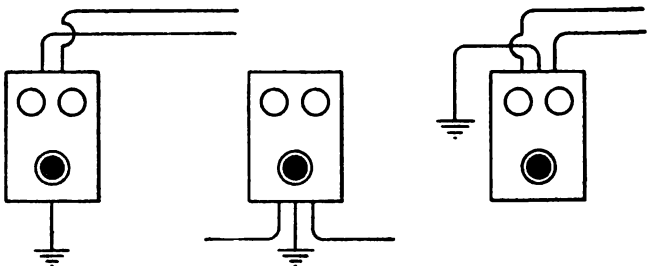
a *whole* to represent a complete substation equipment.

A common symbol is that of Fig. 139. It is so elaborate as to constitute a picture rather than a symbol, but is even then easier to draw than the complete circuits required to say as much as this symbol says, and furthermore it is noncommittal as to the specific circuits embodied. Such a symbol is met in infinite variation of detail. Fig. 140 is a slight simplification, but one which still retains the crank to indicate that it is adapted to operate where magneto calling generator is required. Fig. 141 omits the crank from Fig. 140; if associated circuits permit, this symbol may be taken to indicate that the substation pertains to a central energy system. Fig. 142 reduces the magneto substation symbol by omitting the receiver, the hook and the transmitter (perhaps because the draftsman found them difficult to draw) and Fig. 143 simplifies still further by omitting the generator crank. In Fig. 142 only the signaling equipment of hand generator and ringer is indicated, but if used alone at the end of a telephone line connected with a magneto switchboard it would be understood that a complete substation equipment is symbolized, and that the talking instruments are assumed to be included in the substation indicated by the signaling apparatus only. While Fig. 143 shows a ringer only, the telephone equipment may be assumed if the complete circuit diagram requires it.

In circuit diagrams dealing with central energy systems, the electrical conditions of the substation are simpler than those of a magneto substation having local battery transmission, consequently the electrical

circuits are more likely to be shown than in diagrams representing magneto systems. Notice Fig. 144, which shows very simply a complete talking equipment for a common battery substation. When found in connection with a line running to a common battery switchboard, this symbol should be taken to represent a complete substation telephone, with ringer and condenser, all mounted neatly in a box and fastened to the wall, if you please.

Fig. 145 repeats the symbol of Fig. 144, but adds



147 148 149

Figs. 147 to 149. Substation and Earth Symbol.

a ringer, bridged from wire to wire of the line pair, with condenser in series to prevent the flow of battery current. This symbol now is a complete representation of all that is needed in a common battery substation, but still it should be regarded as a symbol, and read as a single unit of the drawing. Fig. 146 presents another substation in circuit form which is so widely used that it has become an integral symbol for a common battery substation equipment, and should be read as such.

Many line and substation circuits require, in addition to the two line wires, a ground connection in fulfillment of some of the requirements of the central office apparatus. Such a condition may be indicated

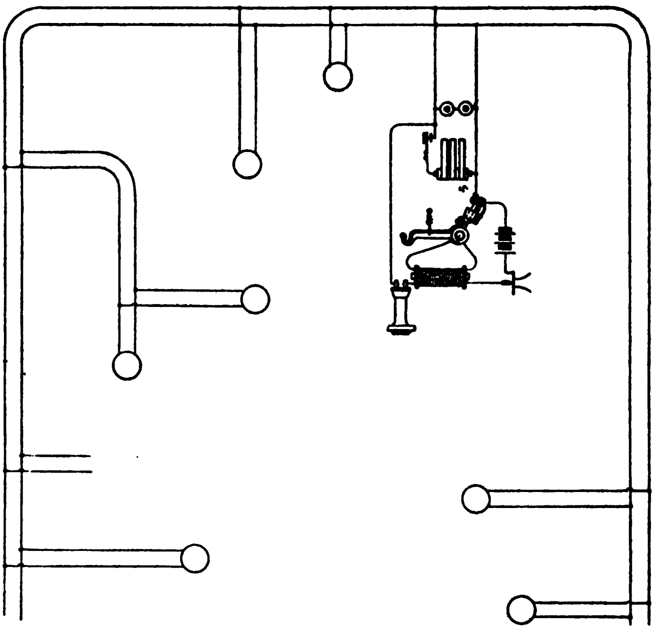


Fig. 150. Party Line, Showing Substation Symbols.

by a third conductor leading in any manner from the substation symbol to an earth symbol near it. Figs. 147, 148 and 149 show this variation as applied to a symbol of the type of Fig. 141.

A drawing forming a part of a United States

patent is taken as the basis for Fig. 150. In this, a private party line is shown diagrammatically. The line consists of two branching conductors terminating in telephone substations presumably all alike. Diagrammatic representation of one substation is made, but the remainder are merely indicated by circles. In many instances rectangles are used to indicate the complete substation, in the same manner as the circles of Fig. 150.

Finally when a pair of conductors run from a switchboard jack and line signal to any nondescript symbol, it may be assumed in beginning to read the diagram that the nondescript represents or indicates a complete substation equipment of such character as to operate in harmony with the jack and line signal or other central office equipment.

LESSON VIII.

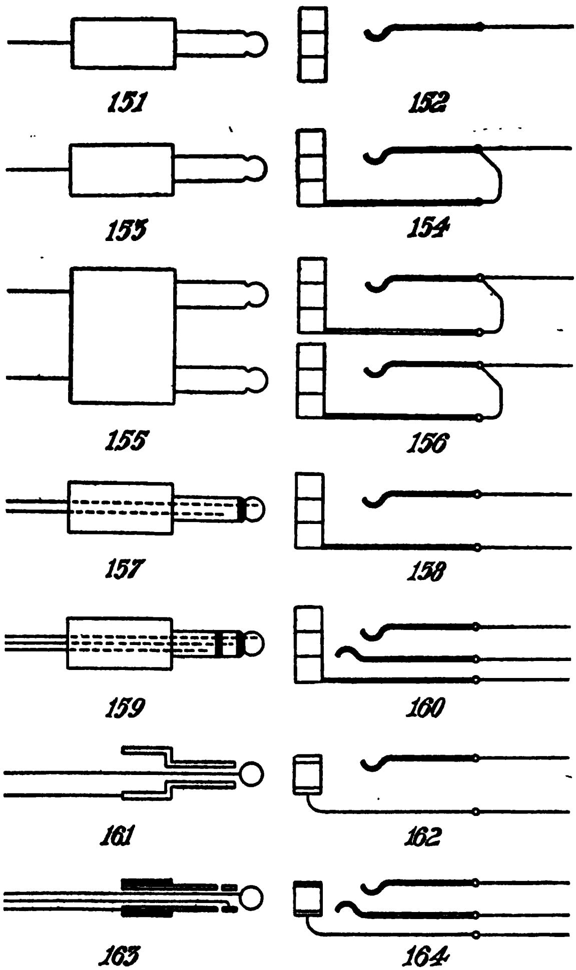
JACKS AND PLUGS.

The jack and the plug jointly form a switching device. It is more logical to consider them as co-operating parts of a switching device which may be separated, similar parts of many such switching devices being interchangeable, than to think of them as separate units, since neither alone is a complete device for any purpose.

The jack is a fixed switch member, usually presenting at the face of the switchboard a cylindrical mouth portion, behind which are spring members, some of them possibly being electrical switches within and among themselves. The body of the jack surrounding the mouth usually is of conducting metal.

The plug is a companion member to the jack, and is adapted to engage certain or all of the jack members. The plug comprises a handle for its manipulation and a projecting shaft for entering the jack and for engaging the springs at the rear of the mouth of the jack. Of conductors, the plug may have one or more; the jack likewise may have one or more conductors to engage electrically the conducting portions of the plug. The plug and the jack which are to co-operate must be designed for each other; beyond this, there are variations in design which are likely to influence the symbols used to represent the devices.

The use of jacks and plugs in a switchboard may



Figs. 151 to 164. Common Plug and Jack Symbols.

be understood from the lesson on simple switchboard principles, preceding this. The line terminals are the jacks, and the switching devices consist of pairs of plugs. Flexible conductors or cords connect the two plugs of each pair. The first function of a plug and jack is to connect the conductor or conductors of the plug and its associated cord with the conductors of the jack, but further operations may be involved to satisfy the requirements of signaling circuits or other details of the switchboard and its operation.

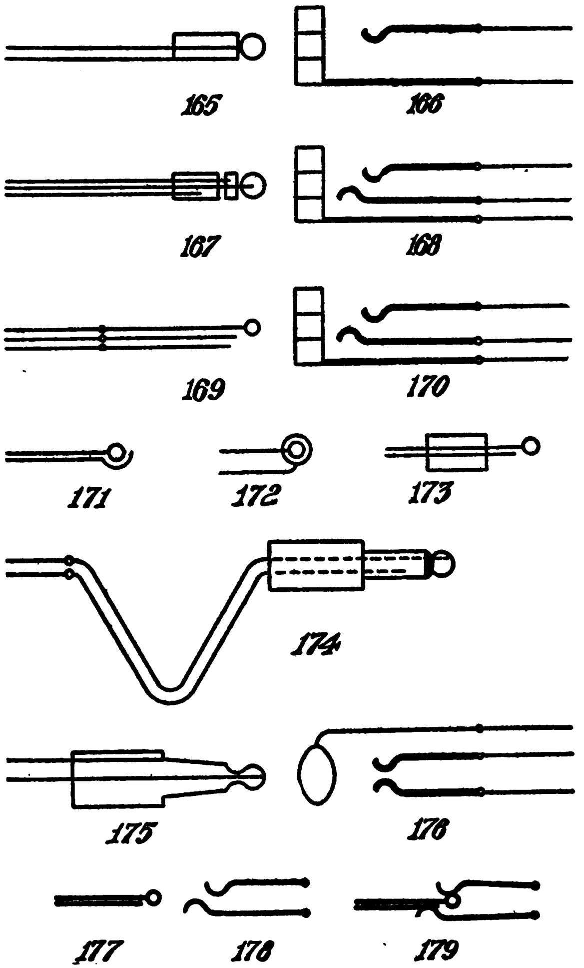
In Figs. 151 to 164 are presented plug symbols of the types most usually met where the plugs are not specialized for some purpose, and also jack symbols most usually met where the jacks are merely offering terminals for the connection of conductors in the plug, without any switching of conductors within the jacks themselves. The solid plug, or one-way plug, is shown in Figs. 151 and 153; in Fig. 152 and jack offers the spring for the conductor which is to take the plug connection; in Fig. 154 the body of the jack and the spring are connected together, thereby offering a greater chance of good contact with the plug, and this form of connection usually is met. A two-conductor plug formed of two solid plugs set in one handle is shown in Fig. 155, and in Fig 156 the twin jacks adapted to take the twin plug are shown. This expedient usually is employed in testing boards, where the degree of insulation between the conductors of a double plug is required to be very high.

Fig. 157 shows a plug of the same general type, but having two conductors, the tip being insulated

from the shaft or body. Fig. 159 shows the body divided; the three conducting portions of this plug are named "tip," "ring" and "sleeve," reading from right to left of the figure. Fig. 158 shows a jack similar to that of Fig. 154, but wired to take the two conductors of the plug of Fig. 157 separately. Fig. 160 shows a jack in which a second spring is present to make contact with the ring of the plug of Fig. 159.

The plug symbols of Figs. 151 to 159 represent side views of the plugs, while Figs. 161 and 163 represent sectional views; otherwise, Figs. 157 and 159 correspond to Figs. 161 and 163. Likewise, jacks of Figs. 158 and 160 correspond to the jacks of Figs. 162 and 164, with a distinction noticeable in the bodies of the jacks; Figs. 158 and 160 are drawn to represent the large cast-body jacks, while the smaller, thinner construction of the body portion of the jacks of Figs. 162 and 164 seems to represent a jack with the body or mouth portion formed from sheet metal, as is the custom with jacks which are mounted in hard rubber strips and set closely together in the switchboard.

In the figures, a plug and a jack are set opposite to each other, the plug being adapted to co-operate with the jack to make a connection; not only does this bring out the relation which exists between the respective plugs and their corresponding jacks, but this is the relation in which the two parts of the plug-and-jack switch usually are located upon the circuit diagram. Occasionally the plug is drawn in its position when inserted in the jack. See Figs. 131, 134 and 179. When freak symbols are encountered, the presence of



Figs. 165 to 179. Unusual Plug and Jack Symbols.

the plug by a jack, or of a jack by the plug, may enable the reader to determine that the unusual symbol is intended for a plug or a jack, as the case may be, and what the disposition of the conductors is.

A number of unusual plug and jack symbols are shown in the group comprising Figs. 165 to 179. In Fig. 165 the tip and sleeve of the plug are shown in side view without insulation or handle, and in Fig. 167, tip, ring and sleeve are shown similarly; in both cases the conductors are taken to the respective parts, stopping on the part to which the conductor is led in the electrical circuit connections of the plug. Fig. 169 shows a plug symbol much used because it is so easy to draw. In this symbol, the conductors are stopped at the location of the parts of the plug to which they are supposed to connect, and the plug itself does not appear at all, except for the circle representing the plug tip. The association of the jack symbol with this very much simplified plug symbol helps to determine the symbol as a plug.

Figs. 171 and 172 show end or front view of the plug, the tip being drawn smaller to show the sleeve behind it. In Fig. 171, the sleeve is not taken all the way around, so that the conductor to the tip may not have to "jump." Fig. 173 is built upon the plan of Fig. 169, but shows the plug handle through which the conductors come to the tip and sleeve.

Fig. 174 attempts to indicate the flexible cord to which the plug is attached. The droop of the two parallel conductors leaving the back end of the plug simulates the droop of a cord fastened at both ends,

and the two small circles at the left of the figure represent conductor junctions, or cord fastener terminals, where the cord is attached to the framework of the switchboard, and the cable wires are connected to the cord conductors.

Figs. 175 and 176 are companion symbols for a plug and a jack taken from a German patent drawing. The two jack springs are of the same length and probably both connect with the tip of the plug. While the plug shows no insulation, yet it must be of two

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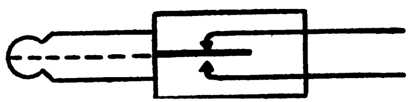

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Figs. 180 and 181. Specialized Plug and Its Symbol.

conductors insulated from each other, to co-operate properly with the jack, and there are two conductors leading from the plug.

Figs. 177 and 178 show associated plug and jack. The jack is noticeable in that only springs are shown, the body portion being omitted. In Fig. 179 the two symbols of Figs. 177 and 178 are shown in connection.

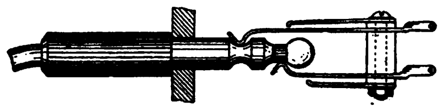
Another class of plug and jack symbol is the class representing plugs and jacks specialized for the requirements of some unusual or peculiar method of operation. Such specialization usually involves both

the plug and the jack, although not necessarily so. Three instances will be studied.

Fig. 180 presents a sectional view of a specialized plug which would seem to operate with any single-conductor or so-called "one-way" jack, such as the jack of Fig. 152 or Fig. 154. In this plug, the part *n3* is isolated, except while the back end of the plug is pressed upon, as would be the case when the plug is being pushed into a jack, at which time the spring *n6* in the shaft of the plug would yield and the part *n4* would make contact electrically with the part *n3*. The screw part *n5* slides back by the same action, and breaks its connection from its conductor in the cord. The plug here shown is therefore a combined switchboard plug and automatic switch or perhaps automatic ringing key. It is well represented by the symbol of Fig. 181, although without the association of the mechanical drawing of Fig. 180 the symbol of Fig. 181, representing as it does simply an unusual specialization of an apparatus part, hardly would be intelligible.

A second case of specialization of apparatus parts in which the plug and the jack co-operate is shown in Figs. 182, 183, 184 and 185. In Fig. 182 a two-conductor plug of unusual conformation is shown fully inserted in a jack, the jack also being of somewhat unusual formation, since the springs of the jack are not in contact with each other, even though the plug is fully inserted. Furthermore, three types of plug are shown, all manifestly to be used with the same specialized jack, since but one jack is shown. The circuit diagram of Fig. 185 is explained by the drawings of

the jack and plugs shown in connection with it. The jack of Fig. 182 closes its switching springs while the plug is being inserted, holding them closed if the plug is stopped when nearly inserted, but not when the plug is fully inserted. The operator's telephone set is



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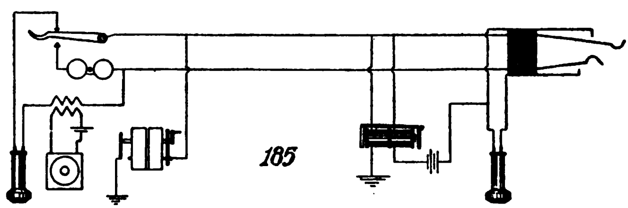

Figs. 182 to 185. Specialized Plugs and Their Uses.

shown at the right of Fig. 185, in a symbol similar to that of Fig. 136, just below the jack.

A call is answered with the plug of Fig. 182. The plug is partly inserted, connecting the calling line to the operator's telephone. The operator takes the number called and forces the answering plug home, which disconnects her telephone from the calling line. The

plug of Fig. 183 is the calling plug, and it is inserted into the jack of the line called without connecting the operator's telephone to that line because of the absence of the large tip. Upon disconnection, when the drop of Fig. 185 has been rung down, either plug will connect its restoring coil and the battery in closed circuit by moving the long spring of the jack, this being accomplished by the enlarged ring back of the tip of the plug. The plug of Fig. 184 is a "listening plug" only; it has no connecting flexible conductors. When inserted in a jack it connects the line to the operator's telephone by spreading jack springs. This plug must be of insulating material throughout, or the line conductors will be short-circuited.

A third set of specialized plugs and jacks is shown in Figs. 186, 187, 188 and 189. In Fig. 186 a jack of two conducting parts is shown, the two parts being electrically in contact with each other. In Fig. 187 is shown a plug adapted to slip between the two conducting parts of the jack of Fig. 186, but having an insulating surface which would permit electrical contact with the upper spring of the jack, but not with the lower spring or anvil upon which the upper spring rests normally. In Fig. 188 is shown another plug, similar in shape, but without the insulating surface, whereby the plug when inserted in the jack of Fig. 186 would make connection electrically with both of the conducting parts thereof. These added details of the mechanism of the jacks and plugs enable the circuit diagram of Fig. 189 to be understood. In Fig. 189, the substation telephone at the left controls as a line

or calling signal the drop at the left of the figure, and the substation telephone at the right controls as a line signal the drop at the right of the figure. When the two lines are connected by the pair of plugs shown in the middle of the figure, it is evident that the conducting plug,

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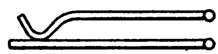

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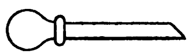

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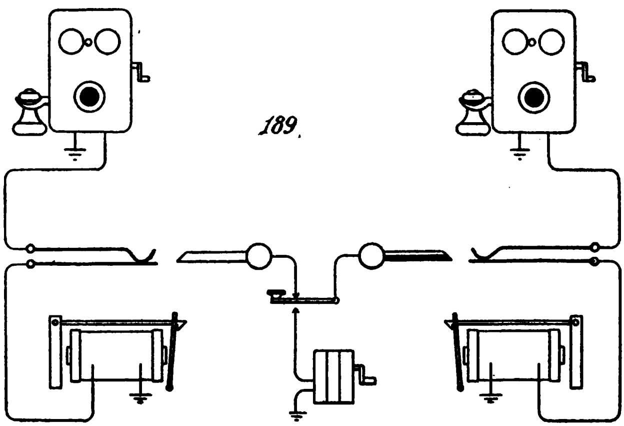


Figs. 186 to 189. Types of Plug Switches.

namely, that similar to the plug of Fig. 188, permits the drop of the left-hand line to remain in connection with the line conduction during the conversation, and thereby to remain upon the circuit as a means for re-

ceiving a clearing signal, while the plug at the right, namely, that one similar to the plug of Fig. 187, disconnects the drop of the line at the right of the figure, not only removing the useless apparatus from connection with the circuit, since but one clearing drop is needed, but also permitting the ringing key of the pair of plugs to be operated to ring upon the line at the right without affecting the drop of that line.

When drawings of circuits involving specialized apparatus parts, such as the circuits of Figs. 185 and 189, are met, the auxiliary drawings, such as those of Figs. 182, 183, 184, 186, 187 and 188, usually will be found accompanying or will be accessible on inquiry.

In addition to the function of connecting with the conducting parts of the plugs, jacks as a general class of apparatus have another and important function, that of switching electric circuits independently of the circuit connections made between the jack and the plug inserted into it.

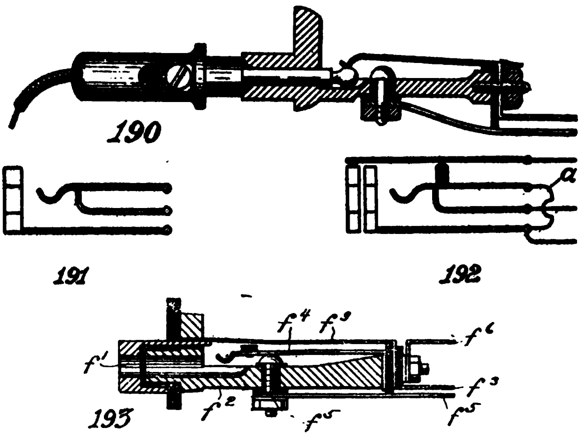
While the switching of circuits by jack springs and contacts within the jack is objectionable for the reason that the contacts never are reliable, the cheapness of accomplishing a switch within the jack by the insertion of a plug as compared with the cost of switching the same circuit by other means, such as a relay, will cause the switching jack to remain in the art as a detail frequently met in the switchboard and in the telephone circuit diagram.

By "switching jack" is meant a jack which switches or modifies a circuit other than any circuits of which the plug conductors form a part. The sim-

plest type is shown in sectional view in Fig. 190 and in symbol in Fig. 191. This jack is substantially the jack of Fig. 122, and is the jack of Figs. 128, 131 and 134. By the addition of insulation between the movable spring and the screw and nut at the back of the body of the jack, it becomes the jacks of Figs. 122 and 125. A frequent use of the switching function of this jack, namely, the function of breaking a circuit when a plug is inserted, is to remove the line drop from the circuit of the line when the line is connected with by a plug. This action is seen clearly by comparing Fig. 128 with Fig. 131.

A more complex switching jack, but still of the general type of the jack of Fig. 190, is shown in sectional view in Fig. 193, and in symbol in Fig. 192. The jack body is of two metallic parts, and it appears that the body of any plug when inserted in the jack will make contact electrically with both of these parts. The top spring of the jack presents a terminal for an external circuit wire, as indicated in the symbol, and normally is in contact with the outer jack body. This is shown clearly in the symbol, but in the symbol the top spring goes forward to the outer jack body, whereas in the physical jack the outer body part goes back to the spring; thus does the symbol ignore the mechanical construction of parts, the requirement as an electrical symbol being only that it shows the electrical relations of the circuit forming parts. Again, in the symbol the inner jack body is represented by the lower line passing to the right and apparently offering a terminal for the connection of an external wire, as

the jack of Fig. 193 does offer it, but the movable spring which is to engage the plug tip is brought out to a terminal also and is connected by a short jumper conductor *a* to the body terminal. This conductor *a* does not exist as a wire in the jack, but is the direct contact of the movable spring in its vertical portion at the back end, where it lies against the back end of

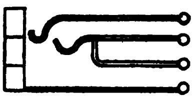


Figs. 190 to 193. Details and Symbols of Switching Jacks.

the cast body of the jack. Again, the contact anvil of the jack passes downward through the body of the jack and then to the right in Fig. 193, whereas in the symbol of Fig. 192 it passes to the right before reaching the body of the jack as represented. In three instances, the mechanics of the jack is not followed in the symbol, but in every detail the electrical circuit features of the jack are represented in the symbol, even to the fact that the tip of the plug must make

contact with the moving spring of the jack before the top spring is lifted from the outer body part.

In Fig. 194, a symbol is presented representing a jack in which the body of the plug makes contact with two conductors, one of which is represented as the body of the jack and the other as a spring located so near the body part of the symbol that the shaft of the plug probably connects with both the body of the



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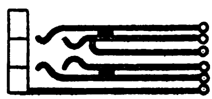

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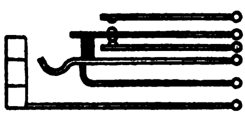

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Figs. 194 to 196. Diagrams of Switching Jacks.

jack and its long spring. This might be checked by measuring the length of the conducting shaft of the plug, but in details of measurements in symbols the draftsman is likely to be unreliable. If the jack of Fig. 194 is associated in the drawing with a two-conductor plug, then the long spring probably makes contact with the shaft, but if with a three-conductor plug, then probably the long spring makes contact with the ring of the plug. The conditions which the

circuit is to fulfill will help to determine, and should decide definitely.

In Fig. 195 is presented a symbol for a jack having the feature of a temporary or transient contact. As the tip of the plug passes through the body of the jack, it connects with the two long springs of the jack, connecting with both of them and therefore connecting them to each other. As the tip passes further, it engages the two short springs of the jack, and, pressing them apart, also presses apart the two long springs, so that the long springs are lifted and the connection just made is broken. The reverse action occurs in the removal of the plug.

In all of the jacks and circuits thus far discussed, the circuits switched have had to do in some degree with the plug inserted. In Fig. 196 is presented a symbol for a jack of the type of Fig. 191, but with an electrical switch added which is controlled by the plug, but is electrically entirely independent and separate from the circuits of the plug. Such jacks are common. The operation may be understood without detailed description.

LESSON IX.

SWITCHES AND KEYS.

An electrical switch, as the term generally is used, means any kind of electric circuit-changing or circuit-controlling apparatus. This definition should not be taken so broadly as to include current-controlling apparatus. To constitute a "switch" there must be the idea of changing the path of the current, rather than changing the value of current; indeed, the switch has to do with the path rather than with any current which may be flowing in the path. A switch must separate two conductors or join two conductors, or both, to come within the definition given; hence the variable-resistance transmitter and other devices which are merely current-controlling devices in nature are excluded from the class of switches, although by some special action even they properly may win that title.

The simplest of switches is the so-called "two-point" switch, which consists of a fixed terminal and a movable terminal, the fixed terminal usually in the nature of a screwhead and the movable terminal merely a simple lever which may be moved upon the screwhead or away from it. It would be well illustrated by the symbol of Fig. 213 with the small circle at the right omitted. In Fig. 132 it was shown open. In Fig. 133 it was shown closed. This simple device bears the title of a "switch." On the other hand, the automatic telephone central office is equipped with

"switches." An apparatus approaching in size a self-playing piano and far surpassing the piano in complexity, containing usually terminals of one hundred subscribers' lines and sometimes as many as twenty trunk circuits, with operating magnets and relays and pawls and wheels and springs innumerable, adapted as whole to connect any one of the one hundred subscribers' lines to any one of the twenty trunk circuits, also bears the simple title of "switch," sometimes amplified to "automatic switch." Verily, this word "switch" is a broad and comprehensive word.

Switches will be discussed under three principal classes, viz.: First, the manual switch or key; second, the electromagnetic switch or relay, and third, the automatic switch, which is a relay or system of relays so highly specialized as to form a class for itself. The intercommunicating switch is a manual switch developed for the same end as the automatic switch, and may be classed with automatic switches.

The key, or manual switch, as used for the purposes of telephony, takes the form of a few small flexible springs operated by a handle. Usually the springs are mounted upon one side (the under side) of a horizontal or inclined shelf, called a keyboard, and the operating handles are upon the upper side of the shelf. The handles may be in the form of push buttons, or in the form of rocking knobs or short levers. The symbols will show them in both forms. The push-button key is the older type, but being the easier for the draftsman it is still used largely in diagrams even where

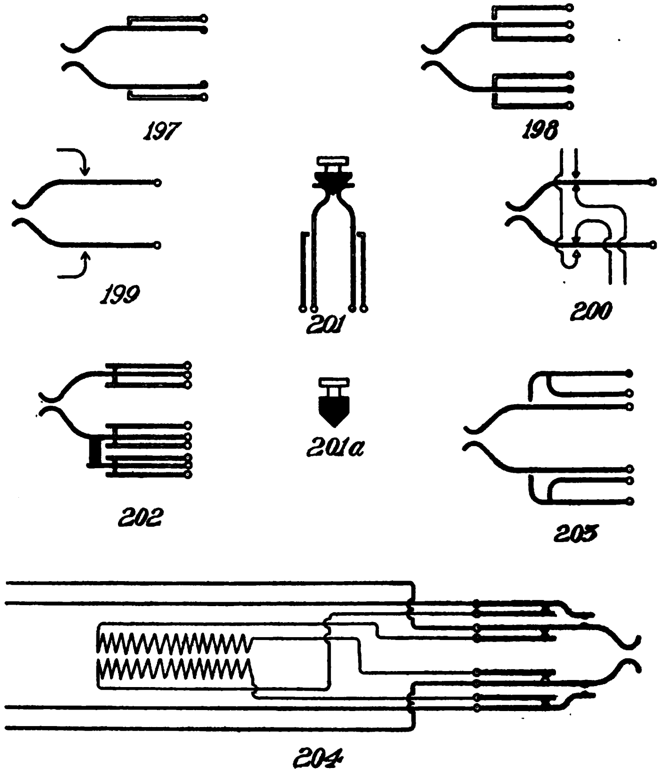
the more modern lever key is in fact the device to be represented.

The push-button type of key usually presents an edge view of a flexible spring or short light arm, with a knob upon the side of the spring, or arm, indicating that the part is to be bent or moved by means of the knob. The lever type of key usually presents a pair of springs which are to be forced apart, sometimes showing also the plunger which is to be forced between the main springs to spread them. The general principle is that a main or movable spring is shown, or a pair of them, and about these are grouped the auxiliary springs, sometimes called contact points, from which the main springs break contact and with which they make contact, the auxiliary springs frequently being arranged to make contacts and other switching conditions among themselves.

In Fig. 197 is shown a symbol for a simple form of double-spring key. This is the symbol usually shown for the operator's listening key. If the two long springs were connected to the two sides of a telephone line, and the two short springs or contact points were connected to the two sides of the operator's telephone equipment, the operator's telephone would be connected to the telephone line whenever the two main springs of the key were spread by a plunger forced between them. Note the key symbol at the left in Fig. 135.

In Fig. 198, the symbol usually used for the operator's ringing key is shown. In this key, the main or operating springs are each associated not only with

outer contact springs with which the operating springs make contact when they are spread, but with inner contact springs from which the operating springs



Figs. 197 to 204. Telephone Key Symbols.

break contact when they are spread. By this means, the two conductors which are connected to the two main springs are taken away from the two conductors

connected to the inner contacts and are connected to the two conductors connected to the outer contacts. In connecting such a key for ringing purposes upon an operator's keyboard, the inner springs lead to the answering plug of the pair, the main springs to the ringing plug of the pair, and the outer springs to the ringing generator of the telephone central office; thus when the operator moves the handle of this key the two switch plugs of the pair are cut apart, on both sides of the metallic line, and the ringing plug only is connected to the source of ringing current, so that the ringing plug only is rung upon. For these circuit connections with such a symbol, see the key symbol at the right in Fig. 135. The listening key of Fig. 197 and the ringing key of Fig. 198 differ from each other because of the requirements of service which are to be met in their use. The possibilities of different combinations in the springs of the keys of a telephone switchboard are countless. A very few of them will be shown in the symbols, since the study of a few key symbols will enable the principles of the symbols to be mastered, after which any and all variations will be read with ease.

The contact points or auxiliary springs of the keys have but little motion, as a rule, and theoretically need not have any movement at all. For this reason they frequently are represented not as springs, but merely as contact points. See Fig. 199, which is a modification of the symbol of Fig. 197, and Fig. 200, which is a modification of Fig. 198. In Fig. 200, the main springs are in a path including the two con-

ductors passing downward, so long as the springs are not spread, but when the springs are spread they are in a path including the two conductors passing upward. In many instances the contact points are represented by circles. See Fig. 228, also Fig. 69. Another modification of the symbol of Fig. 197 is presented in Fig. 201, where the plunger with push-button head is shown in the symbol. The key of the two symbols is the same. In the symbol of Fig. 201 also the springs are shown vertical. The vertical position of the springs has no significance electrically, but the position or direction of the springs may serve to identify the key which is represented, particularly if there be several keys electrically similar in any diagram.

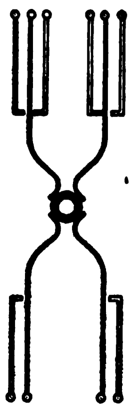
Fig. 202 presents a symbol including below the main switches a set of three switching elements auxiliary to the main switching elements and electrically separate from the main sets. It is obvious that as many auxiliary sets of switching elements as may be desired, and having any desired switching relation, may be added to the symbol of any key.

The symbol of Fig. 203 involves not only a fundamental principle in the construction of keys, but a fundamental principle in the reading of key symbols in a telephone circuit diagram. It is necessary to consider at times not only the switching conditions in the circuits when the key is in either of its two positions (most keys have but two positions), but also the conditions which exist from instant to instant as the key passes from one position to the other. In the

key of Fig. 198 or of Fig. 200, considering the contact points of the key as rigid, the main or moving springs would break contact from the inner contact points before making contact with the outer contact points; thus for a moment the circuit leading to the main springs would be opened. As a ringing key, this is desirable, but for some signaling circuits it might be desirable to hold the circuit closed, changing the path of current from the inner contact to the outer contact without interrupting the flow of current for even the smallest interval of time. This requirement is fulfilled by the key symbolized in Fig. 203. As the operating springs are spread they engage the outer or longer auxiliary springs and for a brief period all three of the springs of each of the two sets are electrically connected with each other; then the longer auxiliary springs take up the movement of the operating springs and are lifted from the short auxiliary springs which in this instance may be regarded as fixed points which do not "follow" the longer auxiliary springs. It is possible, of course, that the physical key represented by the symbol of Fig. 198 may have its springs constructed in such manner that the inner springs may be adjusted to "follow" the moving springs until the outer springs have been picked up, but such a construction is not shown forth in the diagram of Fig. 198 as it is in that of Fig. 203, where the proper switching relation of the springs may be seen clearly and positively.

A key of eight springs is shown in Fig. 204. This key is called a "repeating-coil key" because its ar-

rangement of springs and contacts is such that it will insert a repeating coil into a pair of wires by a movement of its handle. This figure will be taken as an exercise in reading key symbols. The two positions of the key will be referred to as the normal position or position of rest, in which position it is drawn in the figure, and the actuated position. Normally, the telephone line or pair of conductors represented by the



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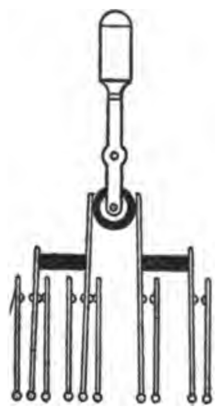

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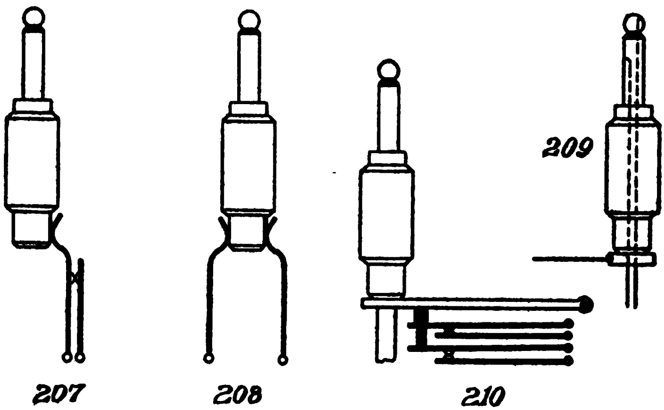
Figs. 205 and 206. Combination Keys.

outer lines entering the diagram at the left passes to the long springs of the key, thence to the inner contacts and to the two ends of the upper winding of the repeating coil. The lower winding of the repeating coil passes to the lower short contact spring and the upper short contact spring of the key, thence to the two springs forming the top and bottom springs of

the symbol respectively, and thence to the inner pair of conductors entering at the left of the diagram. When the main springs of this key are spread and the contacts assume their actuated position, the main springs are in contact with the top and bottom springs of the diagram, and the circuit through the key is shown in the heavy lines of the diagram, passing in upon the inner pair of conductors at the left to the outer springs, directly to the main springs and then directly to the outer pair of conductors leading out at the left of the diagram. The repeating coil, which is connected at its four terminals to the four fixed contact springs of the key, has the four terminals left isolated in the key so long as the key remains in its actuated position.

A key having but one handle, but having two systems of springs so arranged that either system may be operated independently of the other, is called a combination key. Such a key is represented by the symbols of Figs. 205 and 206. In Fig. 205 a plunger is represented as placed between two pairs of operating springs in such manner that it may be pressed between either of the pairs, operating either end of the key, but not both ends at the same time. In the key of the symbol, Fig. 205, the lower end is a listening key and the upper end is a ringing key, so that the operator, having listened or talked upon the cord pair, may ring upon the ringing plug of the pair by the use of the same handle which she will be required to use to remove her telephone set from the talking conductors of the cord pair. This type of key is met in diagrams of cord circuits. In Fig. 206 a key similar

electrically, but differing in symbol, is shown. The different symbols probably would indicate to some extent the mechanical construction of the keys which the maker of the diagram had in mind. Other symbols also may represent a combination ringing and listening key, and may be so taken when appearing in a diagram of a cord circuit. See Fig. 230 and the comment upon it in this connection.



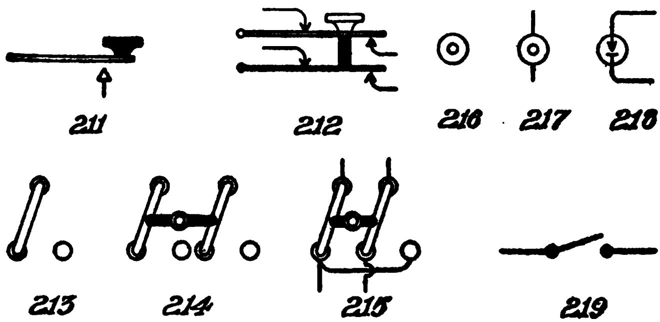
Figs. 207 to 210. Plug Switch Symbols.

In addition to the manual switches or keys operated by the hand of the telephone switchboard operator, there are at times switches operated by the switching plugs when they are lifted from their position of rest, or are returned to their position of rest. These are called plug switches, and four types are illustrated in the symbols of Figs. 207, 208, 209 and 210. In Fig. 207, the symbol represents a switch comprising in part a main or movable spring which pro-

jects into the path of the plug as the plug passes into its position of rest. The plug engages the long spring and pushes it against the shorter spring; when the plug is lifted, the springs are allowed to separate. By placing the short spring or contact upon the other side of the long spring the springs would be separated by the plug when it drops into its position of rest, and would be permitted to connect electrically when the plug is lifted. In Fig. 208 is symbolized a plug switch in which the body of the plug forms a part of the electrical circuit, circuit being closed between the two springs when the plug is in its position of rest. In a diagram including the symbol of Fig. 208, or even of Fig. 207, note should be made to determine whether the body conductor of the plug and its associated cord conductor are not in some way concerned in the circuits which are controlled by the plug switch. It may be that the engagement of the conducting spring of the plug switch with the conducting body of the plug in the diagram is only an incidental detail in the drawing, and does not represent a necessary condition in the circuit requirements of the diagram or of the system which it represents. That the body of the plug and its associated cord conductor frequently are involved intentionally in the circuits controlled by the plug switches is true, and some plug switches consist of nothing more than the engagement of the body of the plug with a conducting seat. The symbol of Fig. 209 represents this simplest type of plug switch. The rectangular element from which the conductor passes to the left is but a metal plate (or the equivalent) upon

which the plug rests, and from which the plug breaks its electrical contact when lifted. When the plug is in its position of rest, the left-hand conductor of the two conductors leading downward from the plug is in electrical connection with the conductor leading to the left from the seat plate of the plug.

Keys of the push-button type, having flat springs upon which the operating buttons are mounted directly, are typified in the symbols of Figs. 211 and 212. Fig. 211 is the standard symbol for a telegraph



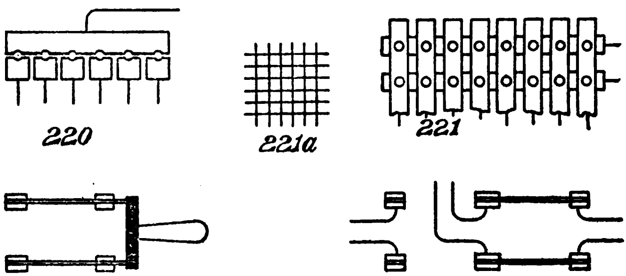
Figs. 211 to 219. Simple Switch Symbols.

key. Fig. 212 shows a ringing key so far as circuits are concerned, but built upon the telegraph-key type of construction. This style of key structure is very widely used in diagrams. It is easy to draw, and shows clearly just what the switching action of the electrical element is, so that whenever and wherever met it may be understood easily. That it represents mechanically the key which it symbolizes is not to be assumed in any instance. This type of symbol is encountered again in Fig. 227.

Simple lever switches are symbolized in Figs. 213, 214 and 215. Fig. 213 shows a single-pole switch and Fig. 214 shows a double-pole switch. These symbols will be understood without explanation. A specialization of the simple lever switch is shown in Fig. 215, and is known as the pole-changer switch. This type of combination of switching elements may be met in other forms, but frequently in the form shown in the symbol of Fig. 215. There are two levers and but three switch points with which the two levers may engage; the middle switch point always is engaged by one or the other of the two levers. The function of the switch is to reverse the relation of the two pairs of wires with respect to each other. When the switch levers are in the position shown in the figure, the left-hand wire at the top connects with the left-hand wire at the bottom, and the right-hand wire at the top connects with the right-hand wire at the bottom. When the switch is in its reversed position, the levers being upon the middle and right-hand contact points, it will be seen that the left-hand wire at the top is connected to the right-hand wire at the bottom, and the right-hand wire at the top is connected with the left-hand wire at the bottom. If the upper pair of wires were connected with a battery, then by the change of the switch the potential would be reversed upon the lower pair of wires, or the direction of current flowing over the lower pair of wires would be reversed.

The symbols of Figs. 216, 217 and 218 are selected symbols representing the ordinary push button such as is used for doorbell work. They are given here that

such symbols may be recognized as switches or push buttons, and not as transmitters, which they resemble very much. See particularly Fig. 30. Figs. 216 and 217 are simple pictures of the door-bell push button, taken at a front view, while Fig. 218 takes note of the electrical elements of the switch. A symbol for a similar key normally closed is used in Fig. 268. In telephone circuit diagrams they are most likely to be found in substation circuits. Fig. 219 is a switch symbol which is most noncommittal as to the mechan-



220 221a 221

222 223

Figs. 220 to 223. Plug Switches and Power Switches.

ical construction of the switch represented, and it is therefore a very broad type of switch symbol.

Fig. 220 is a plug switch. Figs. 207 to 210 have the same name, but are fundamentally different. In Figs. 207 to 210 and the class of plug switch represented by them, the plug usually is independent of the switch operated by it and the plug serves only as a mechanical means for operating the switch. There is about the same relation between the plug and the plug switch as there is between a receiver and a hook-

switch. In the symbols and devices of Figs. 220 and 221, however, the plug is an element of the switch, has no other function, and exercises a selection among the possible circuits of the switch by the position in which it is placed. The plug in this case is a small cone or wedge of conducting material and connects two pieces of metal by touching both of them, as by being wedged between them. By inserting a conducting plug into any one of the circular openings between the long bar at the top and the small squares below it in the symbol of Fig. 220, a connection is established between the conductor leading out of the top of the symbol and a selected one of the conductors leading out of the bottom of the symbol. Such switches are common in lightning-arrester equipments for substations, and in testing apparatus. They are used largely also as battery switches, and in telegraph circuits, because of their large carrying capacity combined with their compact form.

Fig. 221 symbolizes an ancient·type of telephone switchboard, and sometimes it is used in later days as a symbol for a switchboard taken as a whole, without detail. Fig. 221*a* shows the more compact form of the symbol of Fig. 221. Horizontal conducting straps run from left to right, and the vertical straps cross them without touching them. The small circles represent holes drilled through both of the straps, and by inserting a conducting plug into any of the holes the plug would pass through both of the straps and engage both the upper and lower straps, connecting them electrically. By this means, any vertical strap could

be connected to any horizontal strap, or any number of vertical straps could be connected to the horizontal strap. In the earliest type of switchboard, every telephone line had a vertical and a horizontal strap, so that each line crossed every other, and one plug would connect any two lines. An improved type had the telephone lines on short vertical straps only, the long horizontal straps being used as connectors, and two lines being connected together by connecting them to the same cross strap, using two plugs. This type of switchboard required but one-tenth the space of the former type, but it was displaced by the switchboard having the movable plug with the flexible conductor.

In Figs. 222 and 223 are shown symbols of double-pole power switches. These are met in the power-plant portions of telephone diagrams, including the batteries of the switchboards. Fig. 222 shows a single throw switch and shows the handle by which the switch blades are lifted from the switch brushes. Fig. 223 shows a double-pole double-throw switch, omitting the operating handle. The central pair of conductors may be connected to the right-hand pair of conductors or to the left-hand pair, as desired.

LESSON X.

LOCKING KEYS.

In many keys, the circuit controlled by the key is required to be closed but a brief period, during which period the key may be held closed by the hand, a spring being provided to return the key to its normal position and to restore its controlled circuit to normal also, when the hand is removed. For example, the push button of the ordinary door-bell, while not a telephone circuit, is suitable for illustration. This type of key is called a nonlocking key, in distinction from the locking key, which will stay in either position, remaining in its "normal" position until actuated by the operator's hand, and then remaining in its "actuated" position until restored to normal by the operator's hand. A "listening" key is a type of locking key. The operator presses the handle in one direction to connect her telephone with the desired telephone circuit, and the key "locks" and retains the connection between her telephone and the selected circuit until she releases it by pressing the handle in the other direction. Keys are locking or nonlocking according to the requirements of the circuits in which they are found, but, strange to say, the circuit diagram very seldom indicates whether the key is locking or not, unless some special means is provided for locking or unlocking it.

In the symbols of Figs. 197, 198, 199, 200, 202, 203

and 204, the key symbol does not reveal any means for holding the key locked in either position. With the symbols of Figs. 197 and 199 connected in circuit as listening keys, it would be evident that they were locking keys, and with the symbols of Figs. 198 and 200 used as ringing keys, it would be evident that they were nonlocking. It is evident also that the key of Fig. 204 is locking, to retain the repeating coil in the circuit until the operator desires to remove it. With the key of Fig. 201, the locking feature might be shown by showing a plunger of the shape shown in Fig. 201*a*, as a plunger of that shape would remain between the spread springs until pulled back by the hand of the operator, if pushed far enough so that the springs of the key would ride over the angle and upon the parallel surfaces of the plunger. Note again Fig. 135. The key at the left is locking; the key at the right is nonlocking. That such a showing should be made to indicate the locking nature of the key is largely at the option of the draftsman, and the draftsman can not be depended upon. Unless some special provision is made for the locking of the key or for the release of the key, which by reason of its electrical nature must be shown as a part of the electrical diagram, the locking or nonlocking nature of each key must be determined from the requirements of the circuit in which the symbol for the key is found. Some specialized locking keys are shown in symbol in Figs. 225 to 229. The symbol of Fig. 224 is shown to reveal the small difference between a locking and a non-locking key, a difference so small that the drafts-

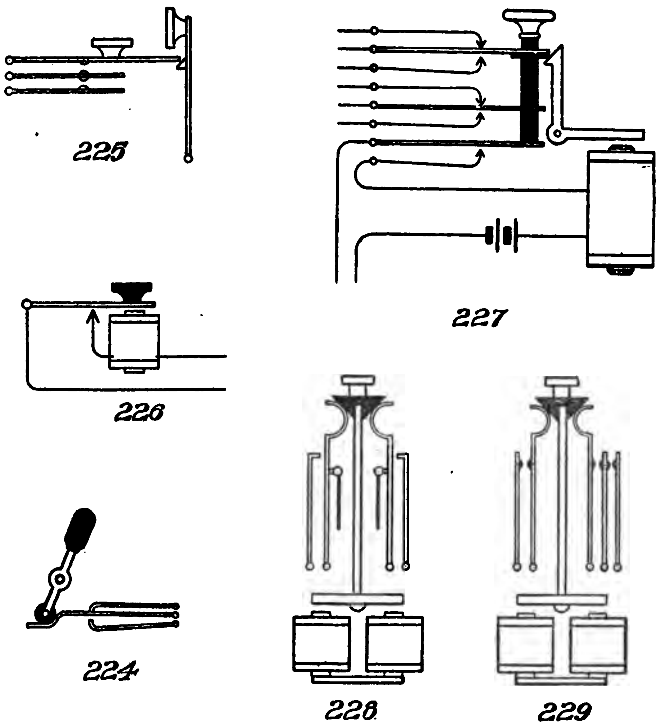
man overlooks it or neglects it, leaving the circuit requirements to determine that feature of the key symbolized. If the lever of the key shown in Fig. 224 be pressed far enough, the black insulating roller at the lower end of the lever will pass the shoulder of the main spring of the switch and the handle will stay over, therefore locking the key; if, however, for some mechanical reason not shown in the symbol, the handle can not be pressed over so far that the black insulating roller will pass the shoulder of the main spring of the switch, the tension of that spring against the roller will force the handle back into the normal position shown, the key will not retain its actuated position unless held by the hand of the operator, and the key is a nonlocking key.

In the symbol of Fig. 225, a key of the push-button type is shown with an auxiliary arm or spring having a latching tooth for locking the main key lever down. In this key, a pressure upon the horizontal knob will close the switch springs together, and they will remain electrically in connection until the vertical knob is pressed to release them. This symbol probably is highly symbolical, although it follows closely the mechanical construction of a well known testing key used in galvanometer measurements.

Fig. 226 shows a symbol representing an electromagnetically locking key of the push-button or telegraph-key type of symbol. When this handle is pushed down it will close a circuit, and if there be current flowing in the circuit as a result of the closing of the key, then the key will remain closed until the

circuit is broken at some other point, to de-energize the magnet and release the key here shown.

In the symbol of Fig. 227, a magnetic latch is symbolized. In this symbol it is shown that when the



Figs. 224 to 229. Some Types of Symbols for Locking Keys.

key handle is depressed the key is locked in its actuated position by some sort of latch which has an electromagnet so arranged that when the magnet is

energized by a sufficient current it will withdraw the latch and release the locking key.

Figs. 228 and 229 show two symbols somewhat similar. Both of these differ from the symbol of Fig. 227 in the detail that the electromagnet must remain energized as long as the key is required to hold its actuated position, the key returning to its normal position as soon as the holding electromagnet is de-energized. In the symbol of Fig. 227 the condition was reversed, the key remaining locked after actuation as long as the magnet remains unenergized, returning to normal upon the first energization of the magnet.

There is a possibility that the keys symbolized in Figs. 228 and 229 are intended for operation either manually or electrically, that the mechanical design of the key is such that it may be operated by pressing upon the knob at the top with the hand, or by energizing the magnet at the bottom so strongly that it will pull the central rod down, carrying the plunger with it to spread the springs and operate the switches. Any symbol must be read to satisfy if possible the circuit conditions required of it. Standing alone, without circuits or connections of any kind, it may have some possible interpretations which would be absurd when the symbol is found connected in a circuit diagram. Refer to the symbols of Figs. 226 and 227. In both of these symbols the electromagnets are energized only through the contacts of their own keys, so that it is impossible to energize them until after the key has been depressed manually. The circuit connections of Figs. 228 and 229 when found in complete

diagrams should show clearly the operation of the keys, if any doubt exist from an inspection of the symbol alone.

Fig. 229 presents one symbol of a three-position key. It would seem from the symbol that when the knob is depressed part way the main springs will make connection with the two springs next to them without connecting at all with the outer spring of the group of three at the right, and that by the further move-

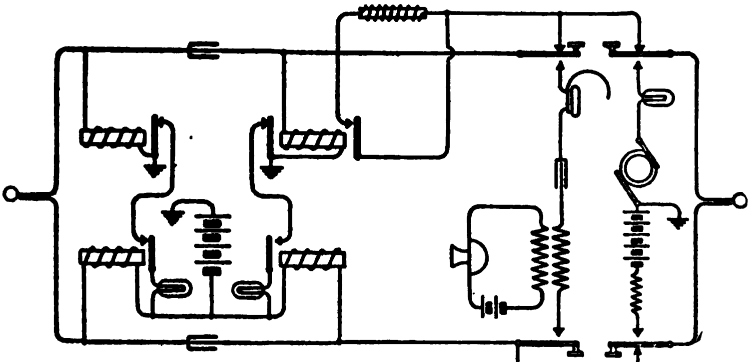


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Fig. 230. Skeleton Diagram of a Plug Pair.

ment of the knob the outer spring at the right would be connected with. This is a construction frequently met with in intercommunicating keys and sets. In the switch symbolized in Fig. 229 it is probable that by the depression of the operating knob to the full depth possible the three springs at the right are connected and that then the knob is allowed to return part way, the electromagnet at the bottom operating to

lock the key in such position that the main springs are held in contact with the springs next to them, leaving the outer spring at the right isolated.

Fig. 230 is presented as an illustration of the embodiment of symbolized keys in a telephone circuit diagram. In this diagram we have a plug pair. The plug symbol at either end is that of Fig. 177. The two plugs are connected by sundry apparatus parts, all presented in recognizable symbols, and including two keys. Apparently there are four keys; there are four key levers and four knobs for actuating them. Two of these levers have the knobs on the under side of the lever, indicating that the knob is to be pushed up to actuate the key, and that the key as shown is in its normal position. The operator's telephone equipment is shown with head receiver, condenser and induction-coil secondary in series, extending from the open contact of one of the upper keys to the open contact of one of the lower keys. By this it becomes evident that the upper and lower keys just above and below the operator's set are the two halves of the operator's listening key, shown separated for draftsman's convenience and possibly for reader's convenience as well, since the wires thereby are permitted to take more direct and shorter paths to their destinations. It is seen also that the two keys at the right, one above and one below, are connected to the right-hand plug and are adapted to separate the two plugs and to connect the right-hand plug to the system of apparatus which contains, apparently, a lamp, an alternating current generator, a battery, a resistance

and an earth connection. These two keys are the two halves of the ringing key, separated for convenience. The four keys are listening and ringing keys of the ordinary type electrically and probably of an ordinary type mechanically, the listening keys operated both halves by a single handle, locking, and the ringing keys operated both halves by a single handle, nonlocking; or even a combination key, with one handle for all of the springs, similar to the construction of Figs. 205 or 206.

LESSON XI.

ELECTROMAGNET. SPLIT AND DIFFERENTIAL CONNECTIONS.

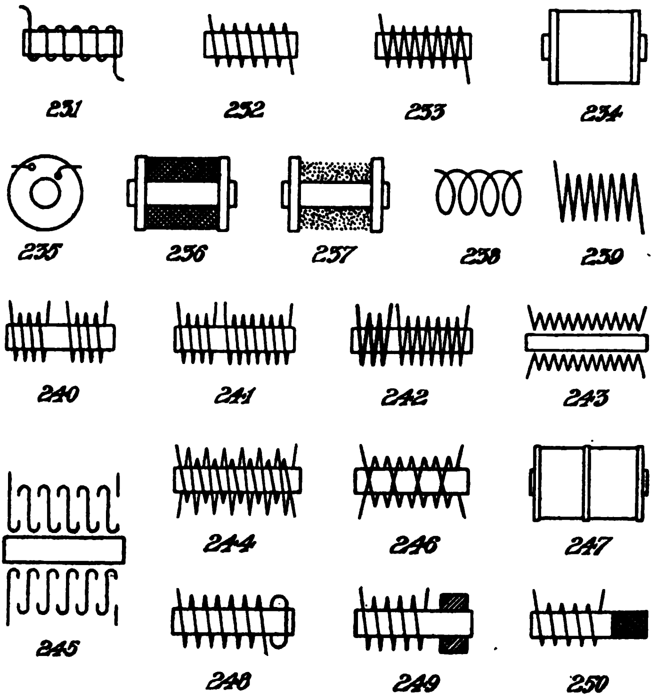
The electromagnet consists primarily of a coil of wire and a soft iron core. See Figs. 231 and 232, which show the two elements properly related. Fig. 233 shows a further simplification of the same symbol.

Variations are found in the shape of the core, in the number of the windings, in the relations of the windings when there are more than one upon the same core, and in the polarization of the core by the field of a permanent magnet. The core shape most commonly met is the straight cylinder, or round rod, of soft iron.

A single-wound straight-core electromagnet is shown in the symbols of Figs. 231 to 239, inclusive. Figs. 231, 232 and 233 show side view of the core and a few turns of conductor about the core; Fig. 234 shows side view of a full spool of wire from which the ends of the core may be seen projecting; Fig. 235 shows end view of a spool, with terminal wires leaving it; Fig. 236 shows a sectional view through a full spool of wire; Fig. 237 shows a similar symbol, but with another adaptation of symbol for showing the cut ends of the turns of wire surrounding the core; Figs. 238 and 239 show the coil of wire only, and properly are not symbols for an electromagnet, certainly not good ones, but sometimes are so used.

Electromagnets having two windings are repre-

sented by the symbols of Figs. 240 to 250. As these symbols are merely amplified by duplication of windings when a larger number than two is desired, symbols having more than two windings are not shown.



Figs. 231 to 250. Straight-Core Electromagnets.

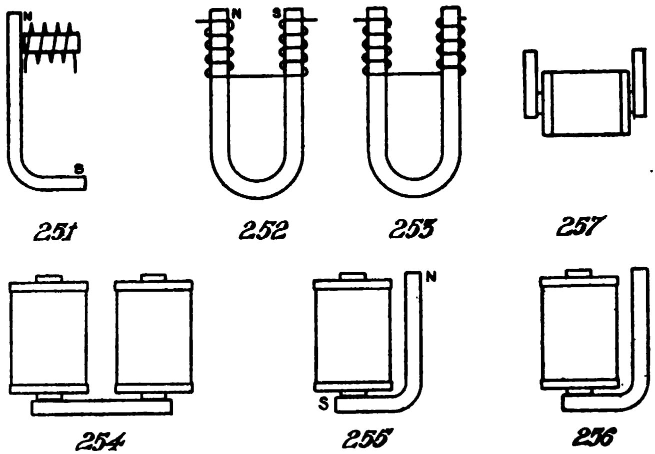
The symbol of Fig. 240 represents a double-wound electromagnet having two windings of equal turns; presumably the windings are duplicates in all respects. Fig. 241 shows unequal windings; unequal

numbers of turns are shown, and probably there is unequal resistance also; the symbol of Fig. 242 emphasizes the unequal resistance by showing one of the windings in heavy line value, typifying a heavier wire used in the winding, and therefore a lower resistance. In Fig. 243 the windings are upon the core, but are shown adjacent to it. In Fig. 244 the two windings are both the full length of the core. In Fig. 245 the two windings are shown separated from the core, and in Fig. 246 they are again shown upon the core. Fig. 247 shows merely a view of a spool, the partition in the middle of the spool indicating that there are two windings, one on each side of the partition.

Fig. 243 does not reveal the direction of the winding upon the core, so that the polarity of the core could not be determined from the symbol even if the direction of current flow in its helix circuit were known. The same is true of the symbols of Figs. 233, 234, 242 and 247.

Compare the symbols of Figs. 232 and 233. In Fig. 232 the direction of winding is shown, and the polarity of the core may be determined by the rule if the direction of current flow is known. In Fig. 233 this is not true. Compare Figs. 240 and 247 and the same is true. Compare also Figs. 243 and 245. In Fig. 245 the core may be imagined placed through each of the coils in turn, and the broken lines thus come to have an interpretation revealing the direction of the winding about the core. In Figs. 244 and 246 also the direction of the winding about the core is determined in the symbol. A discrimination between the symbols

of Figs. 244 and 246 may be noted in the relative directions of the windings. In Fig. 244, proceeding from left to right along both of the windings, the conductor passes in the same angular direction around the core; in Fig. 246, proceeding from left to right, the conductor passes in different directions around the core. In Fig. 245 also the conductors pass in different direc-



Figs. 251 to 257. Bent-Core and Polarized Electromagnets.

tions around the core when traced through from left to right.

In Figs. 248, 249 and 250 a peculiar form of double-wound magnet is presented by the symbol. This is called the slow magnet, slow-acting magnet or sluggish magnet. In Fig. 247 a single turn of a conductor is shown about the core as one of the windings; in Fig. 249 this single turn is shown as a thick

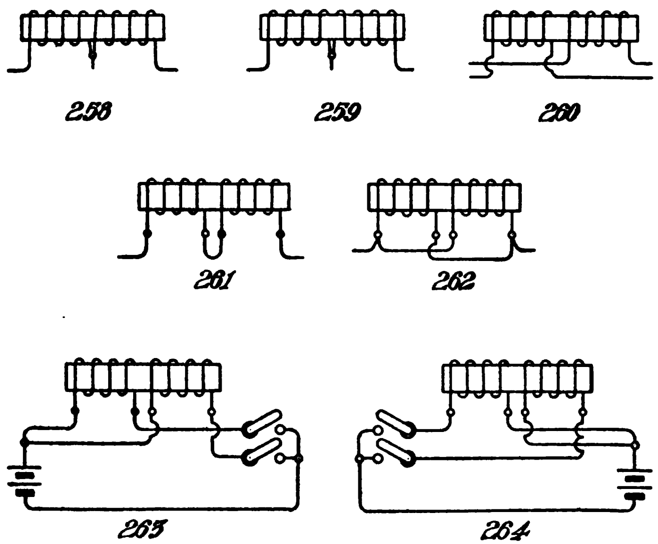
disk, or heavy ring. In construction, it usually is a heavy block of solid copper bored to fit the core and forced upon one end of the core. The symbol sometimes takes the form shown in Fig. 250.

Fig. 251 shows an electromagnet in the field of a permanent bar magnet. In Fig. 252 the electromagnet is combined with the permanent magnet, the coils being placed upon the poles of the permanent magnet.

There are two fundamental forms of electromagnet, the single pole and the double pole. The names are taken to designate the number of magnetic poles presented to the armature which the magnet is to move. Double pole magnets are shown in Figs. 252 to 257 inclusive. In Figs. 252 and 253 the horseshoe shape of core is shown, Fig. 252 being different from Fig. 253 principally in the showing of permanent magnetic polarization of its core, but differing also in the relative direction of its windings on the two poles. Fig. 254 shows a U-shape magnet which is the most common of all forms of double-pole magnets. A heel piece of soft iron connects the rear ends of the two spools. Figs. 255 and 256 show return-pole-piece magnets, and differ from each other only in the showing of permanent magnetism. In Fig. 257 extension pole pieces for both ends of a single spool are shown, whereby the single straight core may present both of its ends to an armature placed parallel to the core.

Certain relations sometimes existing between the windings of multiple-wound magnets may be studied before leaving the subject of magnets in general. The symbol of Fig. 258 shows a split-wound magnet; Fig.

259 a differentially wound magnet. In each of these symbols the windings are so connected in the symbol as to indicate that the device is wound to provide that special connection. Fig. 260 symbolizes a magnet with two independent windings which may be con-



Figs. 258 to 264. Methods of Connecting Windings.

nected in any manner desired. The magnet of Fig. 258, when its helix is traced from extreme terminal to extreme terminal in either direction, at all times has its current effective to magnetize its core, yet either part of the core may be used independently; this is called a split winding. Fig. 259, when traced similarly from either extreme terminal to the other extreme

terminal, in either direction, has its current ineffective or differential upon its core, and the core can be magnetized only when current is flowing through the middle terminal. Both Fig. 258 and 259 are three-terminal electromagnets.

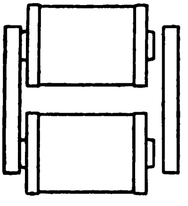
Fig. 261 shows series connection of the coils of a double-wound magnet and Fig. 262 shows multiple connection of a similar electromagnet.

With reference to the direction of current flow through a double-wound electromagnet, Figs. 263 and 264 show the two possible combinations. In Fig. 263 the coils are cumulatively connected, either of the coils magnetizing the core alone, and both together magnetizing it cumulatively, or more strongly as the result of adding the energy of both currents. Fig. 264 on the other hand shows the coils differentially connected; either of the coils may energize the core, but when both of the coils are carrying current at the same time, then the energy of one current is opposed to the energy of the other, and the core is magnetized by the difference only. If the coils are equal in turns and currents, or in any other combination are equal in ampere-turns about the core, then when current flows through both of the coils the core will not be magnetized at all.

The difference between the split and differential electromagnets of Figs. 258 and 259 may be understood by comparing with Figs. 263 and 264. When the full resistance of Fig. 258 is taken in a single circuit, it cannot be connected differentially; when the full resistance of Fig. 259 is taken in a single circuit

it is differential. The relative direction of the windings on a multiple-wound electromagnet always is a matter of importance in reading a circuit diagram.

The feature of utility in the electromagnet is found in its ability to draw a piece of soft iron toward its core when a current is passing through its winding, and to release the piece of soft iron when the current through its winding ceases. The piece of soft iron thus controlled is called the armature of the mag-



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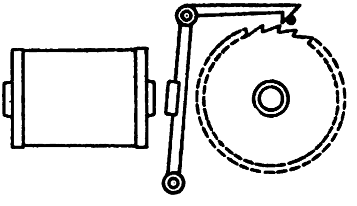

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Figs. 265 and 266. Electromagnets with Armature and Pawl.

net. In a telephone receiver, the armature itself is properly shaped and acts as the sound producing diaphragm of the receiver; in a ringer, with a tapper rod and a ball attached it acts to sound the signal bell. At times the armature may carry a pawl for driving a ratchet wheel, and at other times it may operate an electrical switch. Fig. 265 shows symbol for a double pole electromagnet with armature, and Fig. 266 shows symbolically an electromagnet with armature for driving a ratchet wheel.

LESSON XII.

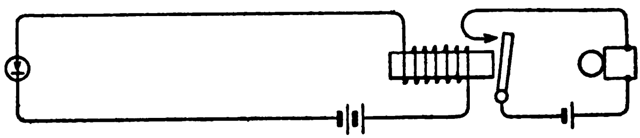
RELAYS.—SIMPLE.

A relay is an electromagnetically operated electric switch. Its function fundamentally considered is that of a connecting link associating two circuits in such relation that the opening and closing of the second circuit may be controlled by the opening and closing of the first circuit. For this purpose, the winding of a relay is included in the first circuit and the switch or contact points of the relay are included in the second circuit. This is illustrated in Fig. 267. The push button at the left is intended to ring the vibrating bell at the right. The button when operated closes a circuit through the larger battery and the winding of the relay, thereby energizing the core of the relay, which then attracts its armature. The armature, pivoted at the bottom, moves its upper end against the adjacent contact point, thereby closing a circuit through the smaller battery, the bell, the armature and the contact point, thus ringing the bell. As long as the push button is open, the bell circuit will be open; as long as the push button is closed, the bell circuit will be closed. The relay of Fig. 267 is a direct-acting relay, since it reproduces in its armature circuit or "local" circuit as it is called, exactly the conditions of opening or closing that are performed in its helix circuit, or "line" circuit.

Fig. 268 is a diagram including a reverse-acting relay. This holds its local circuit open so long as its

line circuit is closed, and vice versa. In this diagram, the opening of any of the four closed push button symbols would open the circuit of the helix; when the circuit of the helix is opened, the armature is released, the local circuit is closed and the bell is rung until the main circuit again is closed.

These two relays show the simplest forms. For a few possible variations in types of relays and ar-



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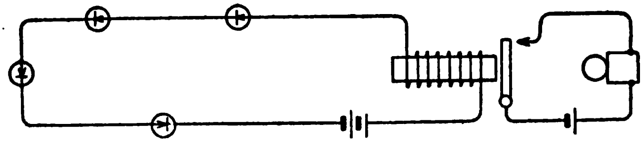

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Figs. 267 and 268. Simple Circuit Combinations with Relays.

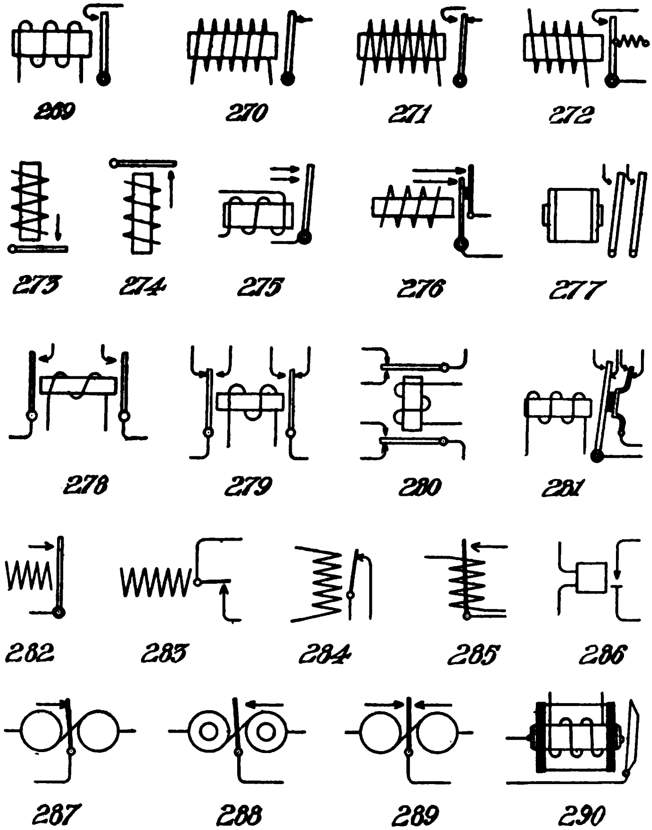
rangements of their contacts, imagine the combination of any one of the electromagnets of Figs. 231 to 265 with any one of the switches of Figs. 197 to 229.

Any arrangement of contact springs desired may be combined with any arrangement of windings. A few typical illustrations will serve to give such an understanding of the principles of relay symbols as to make intelligible any of the innumerable variations which will be met in reading miscellaneous diagrams.

The simplest type of relay must necessarily be the simplest type of electrical switch operated by the simplest type of electromagnet. This is typified in Fig. 269; a two-point switch in this case is formed by a fixed contact point and a movable magnetic lever and a single-wound electromagnet is positioned near the magnetic lever, or armature of the electromagnet.

Fig. 269 gives a simple symbol for a two-point direct-acting relay. Fig. 270 symbolizes a reverse-acting relay of the simplest form. Fig. 271 shows a similar symbol for a make-and-break relay; it is the magnet of Fig. 233 combined with the switch of Fig. 224 or of Fig. 213. Fig. 272 shows an elaboration of the symbol of Fig. 269, a tension spring being added to the armature, to return the armature to its original position, after it has been moved by the magnetism of the core and has been released upon the cessation of the current energizing the core. The retractile spring, or some retractile means, usually is assumed in a relay symbol; it is shown but seldom. Sometimes the armature is shown inclined as in Fig. 270, indicating that the restoring force probably is gravity. In Fig. 273 it would be true, apparently, that gravity would restore the relay to a condition of open contact, but unfortunately for that theory, that symbol is just as likely to be found in the position shown in Fig. 274, where certainly gravity was not considered when drawing the symbol. The rule is that the retractile means is omitted, and it must be assumed that the armature retracting means exists in any symbol where such a means is required.

Plural contacts are shown in the symbols of Figs. 275 to 281. The complex arrangements of plural contacts are simplified by showing two armatures in the symbols of Figs. 277 to 280; it is likely that the physi-



Figs. 269 to 290. Simple Relay Symbols.

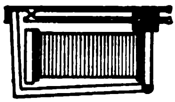
cal relays have but one armature, the double armatures being but a convenience in drawing the symbol. Figs. 277 and 278 show the switch of Fig. 201; in one symbol the two armatures are at one end of the core and in the other they are differently arranged. Figs. 279 and 280 show the switch of Fig. 198. Figs. 276 and 281 show auxiliary contact springs carried by the armature in lieu of a second armature.

Figs. 282 to 285 show symbols in which the magnet symbol of Fig. 239 is used. The armature lever and contact point are combined with the helix in almost any manner, being a combination of helix and switch into a symbol for a relay without reference to the core. Fig. 286 presents a magnet in its side view without showing either the spool heads or the core ends, the relay contact being shown without detail of the armature. The symbols of Figs. 282 to 286 do not suggest to the reader the operation of the relay so well as do other symbols of the group; they are found in foreign diagrams more frequently than in American.

Figs. 287 to 289 show end view of the magnets of the relay, combined in each case with a symbolized armature and contact. Fig. 290 shows a symbol in which the core forms a part of the local circuit, and carries the fixed contact point. The symbol follows closely a once popular mechanical design of relay.

Fig. 291 is a symbol, but shows the type of mechanical construction of the relay. The magnet is of the style of Fig. 257, and the armature is of appropriate shape to operate the switch springs. In Fig.

292 the magnet is of the style of Fig. 257, but the pole pieces are bent toward each other, the armature



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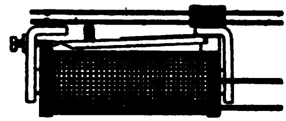

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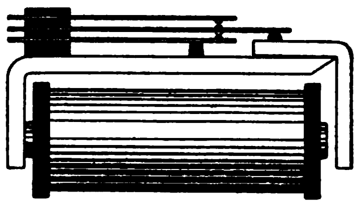

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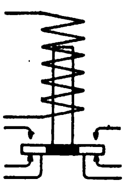

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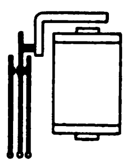

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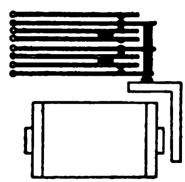

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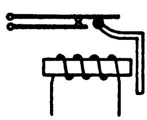

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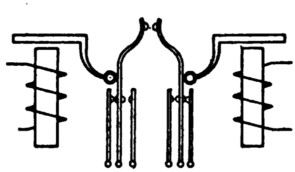


298

Figs. 291 to 298. Return-Pole and Bell-Crank Relays.

being hung between the pole pieces and the core. This arrangement of core, poles and armature shows the seeming anomaly of an armature moving away from its core when attracted. The tendency of armature movement is to close the air gap of the magnetic circuit, and this is done by an upward movement of the left-hand end of the armature of Fig. 292, thus lifting the lower of the switch springs and closing the switch contacts. Fig. 293 symbolizes a common type of return-pole-piece relay with bell-crank armature. Fig. 294 shows a solenoid relay in which the armature occupies the place of the core. When a current passes through the solenoid, the rod is drawn into the coil, and the switches attached to the end of the rod are operated.

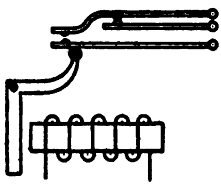
Any of the symbols previously given may be used for any of the types of relays here shown with mechanical detail. In addition, the mechanical construction of the bell crank armature gives another set of symbols which also are used for symbols to represent any type of mechanical construction. Bell crank symbols are shown in Figs. 295 to 298 inclusive.

Fig. 295 symbolizes the relay of Fig. 293. In such a symbol, as in such a mechanical relay, the switching springs lie parallel to the core and may be of any number and of any arrangement of contacts. In Fig. 296, the magnet symbol of Fig. 234 is combined with the switch of Fig. 227. Fig. 297 shows another form of bell-crank armature symbol. Fig. 298 shows two such symbols so related that the energization of either relay alone will operate its own set of

three springs, and the energization of both of the relays at the same time not only will operate the two sets of three springs each, but will cause the two long springs of the two sets to be moved into contact with each other.

It is evident that the electromagnet of a relay may be wound in any way desired, and with as many windings as desired, and with any relation.

A make-before-break relay is symbolized in Fig. 299, and Fig. 300 shows another symbol used for two



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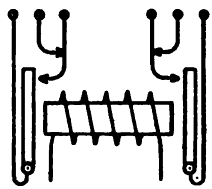


300

Figs. 299 and 300. Make-Before-Break Relays.

sets of the same arrangement of contact springs. This arrangement of contacts is made to prevent the breaking of the controlled circuit even for a very small interval of time, and also when used in combination with a slowly acting armature they are used to give a short impulse only when the helix circuit of the relay is opened or closed, the current permitted by the armature springs being but a short impulse, regardless of how long subsequently the helix circuit may remain opened or closed.

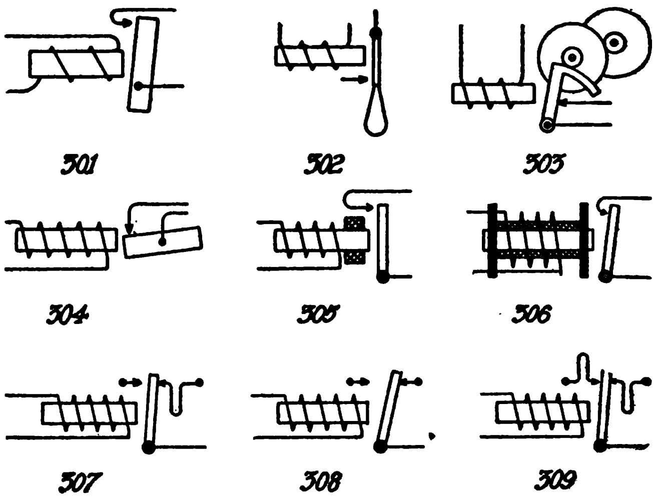
LESSON XIII.

RELAYS.—SLUGGISH. LOCKING. INTERLOCKING.

Relays with slowly acting armatures usually have the slow element of their nature indicated by some modification in some standard symbol. Fig. 301 gives a symbol indicating by the size of its armature the sluggishness of the armature action. It is well known that a larger mass will move more slowly under a given force, and this is taken into consideration in drawing the symbol. Fig. 302 typifies a relay having an armature with an air vane or fan attached. Fig. 303 shows a clock train as a delay element, a type of slow relay much used in automatic telegraphs. Fig. 304 shows a common type of slow relay symbol, representing closely the actual construction. This relay is used also when a relay is required which is responsive to alternating current. Fig. 305 shows the sluggish-magnet symbol of Fig. 249 in combination with a relay armature and contact, thus producing a slow relay. Fig. 306 shows a symbol for the same style of relay, with the copper ring as a shell upon the core, the winding being wound upon the copper shell. A solenoid relay, such as Fig. 294, usually is a sluggish relay.

Still another symbol for a slow acting relay is shown in Fig. 307, in which it is indicated by the bent spring at the back contact that the contact point follows the armature during the early part of its move-

ment, thus delaying the breaking of the armature circuit. In Fig. 308 a reverse function is involved, the closing being delayed instead of the breaking, and the only indication of delay is the wide distance which separates the armature and its front contact. Such an indication is likely to be deceptive, being uninten-



Figs. 301 and 309. Relays with Delayed Contacts.

tional on the part of the draftsman, unless the circuit conditions require the delay.

When reading a circuit in which two relays have their helix circuits so related that they receive current simultaneously, as when the two windings are in series or in parallel, it is necessary to consider the order in which the contacts of the relays are changed by the movement of the armatures. If either relay has an

indication of sluggishness, and the remaining relay has not, then the relay not so indicated will close its contacts before the sluggish relay. If neither relay is indicated as sluggish, then it should be assumed that the back contacts of both relays are broken before the front contacts of either relay is made. In connection with such a study of simultaneously charged relay cores, the requirements of the circuit for satisfactory operation of its parts must be taken into consideration.

The back contact of the armature of Fig. 307 is called a "following contact" because the contact follows the armature for a portion of its movement. When placed in front of the armature it is called a "yielding contact," but is in turn a following contact when the armature is released. In Fig. 309 a symbol is shown in which the armature is provided with following and yielding contacts both front and back. The inference would be that the front contact is picked up before the back contact is dropped, and upon release the same would be true, so that the electric switching conditions of the make-before-break relay are attained, the relay of Fig. 309 being electrically equivalent to that of Fig. 299 or Fig. 300.

Fig. 310 is presented as an illustration of the use of fast and slow relays in combination, as well as for an exercise in general skeleton-circuit reading.

The only indication that the relay *e* is a sluggish relay is found in the size or thickness of its armature, as compared with the armatures of relays *d* and *c*. This diagram represents a cord pair at the central office,

a line equipment with one line jack, a line, a substation equipment in the symbol of Fig. 146 with an optional change in the transmitter element of the symbol, and, finally, a coin-collecting device. This coin-collecting device is so constructed that a path from the line *1* to earth is formed when a coin is dropped into the slot of the device. A coin is in, as represented in the diagram, hence the path from *1* to earth is closed, and current is flowing from battery *b* at bottom of diagram through contact and armature of relay *e*, winding of relay *d*, contact and armature of relay *c*, wire *1*, wire *4*, coin-switch springs *f* and *f2*, and earth back to battery *b*. Relay *d* is energized and is shown properly in the diagram with its armature in its attracted position, and with its armature circuit closed. Upon the insertion of the plug in the jack *a*, current will flow from battery *b* of the cord pair through resistance and signal lamp, body of plug, ring *a3* of jack, wire *3* and winding of relay *c* to earth, energizing relay *c*. This interrupts the circuit first described, because relay *c* attracts its left-hand armature. By the attraction of the right-hand armature of relay *c* path is closed for current through the lower battery *b* up through wire *6* and through the winding of relay *e* and thence through the contact to earth. This energizes relay *e*. Note that in the circuit traced through the coin device, the breaking of the circuit at the left-hand armature of relay *c* occurred before the movement of the armature of relay *e* was begun.

Upon the removal of the plug from the jack, relay *c* is de-energized because its energizing circuit is

broken; by the de-energization of relay *c*, relay *e* also is de-energized because the release of the right-hand

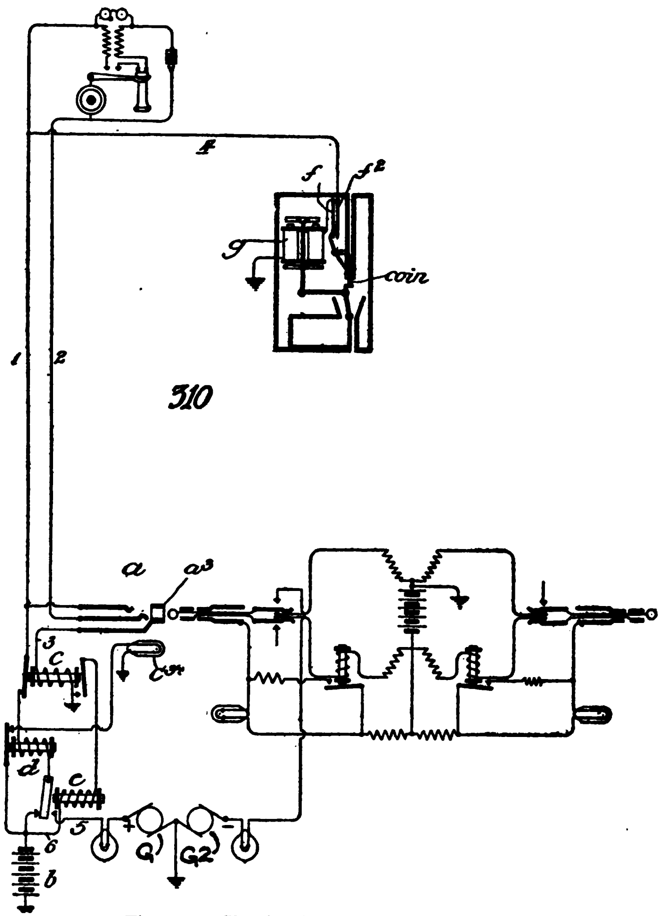


Fig. 310. Circuit with Fast and Slow Relays.

armature of relay *c* breaks the helix circuit of relay *e*. These two relays are released practically at the same time, but the relative armature speeds are indicated by the size of the armatures, and the armatures of the relay *c* must be considered as acting before that of relay *e*. With *c* released and *e* still in its actuated position, circuit through the coin device is found not through battery *b*, but through generator *G*, through wire *5*, through armature of *e*, through winding of *d*, through closed back contact of left-hand armature of *c*, through wire *1*, wire *4*, switch *f2-f* and magnets *g* to earth. This condition lasts but a very short interval, because sluggish relay *e* immediately changes the circuit back to that circuit first traced in this study.

The conclusions to be reached after this study of Fig. 310 are that the magnets *g* are not responsive to the current through them caused by the battery *b*; otherwise there would have been no circuit for the generator *G* through the armature of relay *e*. Also, that the magnets *g* are responsive to current through them from the generator *G* and dispose of the deposited coin in response to that control, after which the switch *f2-f* is opened; otherwise, the relay *d* would remain permanently energized, and this would cause the lamp *c3* to burn permanently, since the relay *d* closes by its armature a path through battery *b*, lamp *c3* and earth. A further conclusion is that the electromotive force of the generator *G* is greater than that of the battery *b*.

Do the switch *f2-f* and the magnets *g*, when considered together, form a relay? The switch cannot

be called an "electromagnetically controlled" switch because it is impossible, so far as the diagram shows, to close the switch electromagnetically, a coin being required to close it. Such a combination of elements should not be called a relay.

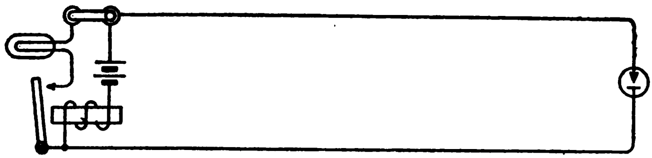
It occurs frequently that a relay's own contacts are used to switch circuits which include its own winding, or some of its windings, if there be several. One class of these may be called "locking" relays, a type of relay frequently met. This is a relay so associated in a circuit that when its armature is attracted it will by its own contacts close a circuit to hold its armature in the actuated position, holding its core magnetically energized. Such a relay in itself may be but an ordinary relay, deriving its name "locking" from its circuits and method of operation rather than from any feature of the relay itself.

A locking relay with its circuits simply arranged is shown in Fig. 311. By closing the push button at the etxreme right of the diagram, current will flow from the battery through the relay helix and through the push button and energize the relay. Upon the closing of the contact by the armature of the relay, current will flow also through the battery, the two-point switch, the lamp, the relay contact and armature and the helix of the relay, thus giving a circuit for current even after the push button has been released. The lamp will glow and the relay remain energized by means of this locking circuit until the two-point switch between the battery and the lamp is opened, after which the relay may be energized and locked

again only by the operation of the distant push button. In Fig. 312 a similar arrangement is shown, but in this latter figure the relay has two windings and the energizing and locking circuits are entirely separate, conductively.

A locking relay may be unlocked by another relay, as is seen, substituting the contacts of the relay of Fig. 270 for the two-point switch in either Fig. 311 or Fig. 312. It sometimes may be unlocked also by shunting the locking coil, thereby reducing the current through the locking coil and reducing the magnetism to a point where the armature is no longer held. It may be unlocked also, when proper circuit arrangements are provided for a relay having two windings, by neutralizing the magnetism of the locking winding by current through another winding; in other words, by connecting two of its windings differentially its armature may be released and the relay unlocked. With this thought in mind, read very carefully the diagram of Fig. 312, taking note of the direction of polarity of the two batteries and the direction of the two windings and the resultant currents. It will be seen that the first push upon the button at the right of the diagram will energize the relay, and that the locking circuit will continue and increase the energization. Also that a push upon the button while the relay is locked up will produce a current through the push-button winding of the relay which augments by its resulting magnetism the magnetism of the locking circuit. If either battery were reversed and if the resistance of the circuit wiring to the push button,

which seems to be rather a long circuit, be considered as equal in resistance to the lamp, then equal cur-



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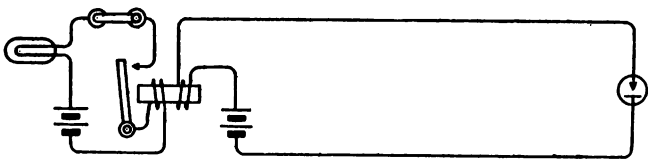

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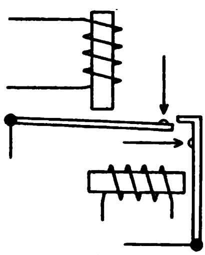

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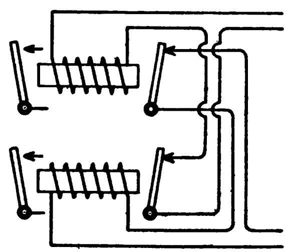

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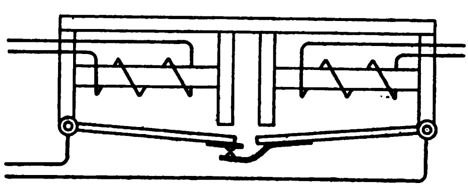


315

Figs. 311 to 315. Locking and Interlocking Relays.

rents will flow from the two batteries, and a neutral state of magnetism will be produced in the relay when both of its circuits are closed. A quick push upon the button should energize the relay and light the lamp, locking the relay and continuing the burning of the lamp indefinitely, but another quick push upon the same button should unlock the relay and put out the lamp. Incidentally, also, if the push button were held closed the relay would vibrate and cause the lamp to flash, particularly if the armature were a sluggish armature, since with its button winding closed at first it would pull up its armature; then by closing its locking winding through its own armature it would but neutralize the magnetism of the button winding, thus releasing the armature. Upon the release of the armature and the consequent breaking of the locking circuit, the magnetism of the button winding would become effective again to attract the armature, and the cycle would be repeated indefinitely, flashing the lamp repeated as long as the push button is held down, and in the end leaving the lamp either dark or glowing, as the instant of release of the push button might determine.

Interlocking relays are shown in symbol in Figs. 313 and 314. In Fig. 313 the armatures are interlocking, and in Fig. 314 the circuits are arranged to the same end. In Fig. 313, when either armature is attracted, its free end interferes with the movement of the free end of the other armature, and the second armature therefore cannot be moved to close its contact. In Fig. 314, the helix circuit of each of the re-

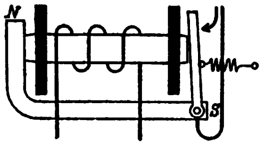
lays is taken through the normally closed armature contact of the other relay. When either relay attracts its armature, it opens the helix circuit of the remaining relay, making the operation of the second relay impossible.

Fig. 315 shows a compound relay, which in its nature is a pair of interlocking relays. When the right-hand armature is attracted the contact is closed, but when the left-hand armature is attracted the contact is broken. While the left-hand armature remains attracted the right-hand armature has no control over the armature circuit.

CHAPTER XIV.

RELAYS.—POLARIZED. REVERSE ACTING. VIBRATING.

By providing for an initial magnetic polarization of a relay core, the relay may be made to discriminate between currents of different directions by reason of the different magnetic effects in the core ends presented to the relay armature. Thus, with a predetermined initial polarization, there will be a predetermined pull upon the armature at all times when no current is flowing through the helix. When a current flows through the helix in one direction, the attraction of the core for the armature will be increased, while a current flowing through the helix in the opposite direction will cause the attraction for the armature to decrease. The symbol of Fig. 316 discloses a polarized relay which holds its armature normally attracted. When the current through its helix is of a direction to produce a magnetism of the same polarity as that of the permanent magnet the armature is held all the more strongly. When, however, the current through the helix is in the reverse direction, and is proper in strength, the polarity of the core may be neutralized and the armature released, closing the armature contact. It is evident that the permanent magnet of such a relay may be replaced by a second winding upon the relay core, through which current passes from a battery for the purpose of polarizing the relay to hold its armature when idle. Such an ar-



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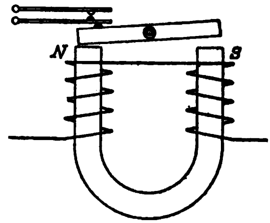

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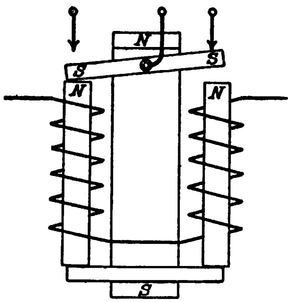

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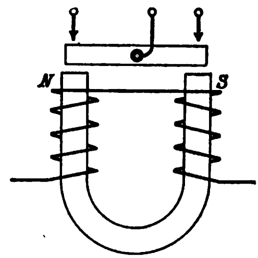

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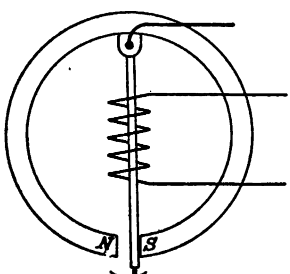

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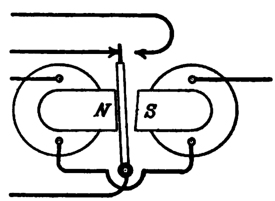

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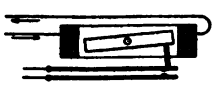

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322

Figs. 316 to 323. Polarized Relays.

rangement gives to the relay a polarization which is adjustable in degree by controlling the current flowing through its polarizing coil.

In mechanical construction, types of polarized relays vary widely, and their symbols as adapted from the different mechanisms also vary widely. The symptom which may be taken to indicate a polarized relay is the occurrence near each other of a permanent magnet, a helix and a contact, with or without armature.

In Fig. 317, the armature is pivoted in the middle, with its contact-controlling end against the *N* pole of the permanently magnetized core. The helix is so wound in direction upon the two poles that when it is desired to operate the armature the *N* pole is weakened and the *S* pole is strengthened, thereby moving the armature. Upon release, the spring of the contact members would return the armature to its position as shown, or a retracting spring may be assumed.

Fig. 318 shows a symbol for a polarized relay having three positions for its armature. Retracting springs must be assumed by which the armature is returned always to its middle position, in which position it is shown in the symbol. Current in one direction through the helix circuit will move the centrally pivoted armature in one direction, and current in the other direction will move the armature in the opposite direction, thus making it possible to close optionally either of the two contacts of the relay, according to the direction of current flowing through the helix.

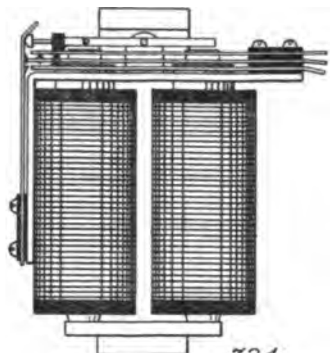
The polarized relay, as usually built, is in its nature a locking relay, and will operate to leave its

armature in its last position unless retractile springs are provided. In the relay of the symbol of Fig. 319, the armature will remain in the position so long as no current flows through the helix, unless retractile springs exist, and they are not shown. When current flows through the helix to move the armature to its reverse direction, the armature will so move, and then will remain in that position until a reverse current through the helix reverses the position of the armature. This peculiarity of the polarized armature must be taken into consideration in reading circuits containing such apparatus.

The symbol of Fig. 320 shows a relay comprising a horseshoe magnet and a single helix, the armature being of soft iron and moving within the helix, its end swinging between the two poles of the permanent magnet. When the helix current polarizes the free end of the armature *N* it will swing to the *S* pole of the permanent magnet, and will remain there after the current through the helix has ceased. Upon the beginning of current through the helix which polarizes the free end of the armature *S* it will swing to the *N* pole of the permanent magnet and remain in that position. In Fig. 321 the permanent magnet is not shown, but the armature movable between the two pole pieces is typical of a polarized device. In Fig. 322 the symbol of Fig. 321 is shown in simplified form. Fig. 323 shows in its symbol a polarized armature swung within a helix, the helix being shown in section. A striker attached to the armature operates the pair of contact springs when current in a prede-

termined direction swings the right-hand end of the armature downward. Current in the opposite direction would swing the right-hand end of the armature upward, and would not operate the contact springs.

In the symbols of Figs. 316 to 320 inclusive the direction of winding and the polarity of the permanent field are shown. This enables the reader of the symbol to determine the direction of current flow required to move the armature in a predetermined direc-



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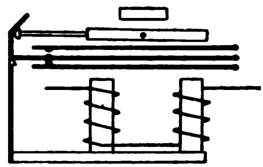


325

Figs. 324 and 325. Reverse-Acting Relay and Its Symbols.

tion. In the symbols of Figs. 321 to 323, inclusive, the direction of winding is not shown and conditions of the circuits in which the relay is included must determine the direction of current required to actuate the armature. In Fig. 323, arrows adjacent to the leading-in wires of the helix may be taken to indicate that current in the direction of the arrows will be effective to close the armature contact.

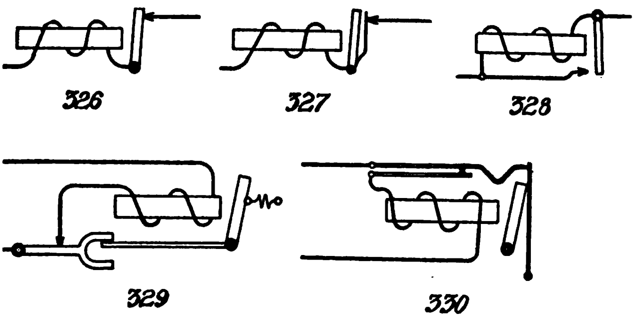
It is required sometimes of a piece of apparatus

that it perform its operating functions upon the cessation of the energizing current, rather than upon the beginning of the current. An instance which may be cited in particular is the release magnet upon an automatic switch, which usually releases or restores its switch upon the cessation of the current which has energized the release magnet. Similar duty sometimes is required of a relay. A locking relay of such a nature is presented in mechanical detail in Fig. 324 and a symbol which has been used to represent it is presented in Fig. 325. In Fig. 324, the vertical spring at the left is merely a locking spring. It is provided with two teeth for locking purposes, and with an inclined surface to receive the thrust for unlocking the relay contacts. The electrical switch is of three springs, and the black insulating strut between the two outer springs, appearing near the left end, spaces the outer springs apart without interfering with the middle or long spring. The armature is pivoted in the middle and carries an insulating block for depressing the switch springs, and a projecting stud, probably insulated also, for pressing the locking spring outward. The armature may be tipped in either direction, according to the direction of the current through the coils of the relay. Normally, the long spring is in contact with the upper spring. When the left end of the armature is drawn downward by the magnets, the insulating block of the armature pushes down both the upper and lower springs, until the long spring is caught between the teeth of the locking spring, the long spring meanwhile, by its own spring tension,

keeping contact with the upper spring, and continuing so in the depressed position of all three springs as long as the operating current continues to flow through the coils. When the energizing current ceases, the armature is released and the top and bottom springs are released, moving upward by their own spring tension, but the long spring is detained by the locking spring. Thus the upper spring moves away from the long spring and the under spring moves upward into contact with the long spring, and the condition of the switch is changed, the change being effected upon the release of the armature, rather than upon its primary actuation. The switch is restored by operating the armature in the other direction, by passing current of the opposite polarity through its coils. The rising of the left end of the armature presses the stud against the inclined face of the locking spring, pressing the locking spring away from the long spring of the switch and releasing the switch upon the beginning of the release-current impulse. In the symbol, Fig. 325, the small rectangle above the pivot of the armature represents the end of the polarizing permanent magnet.

Vibrator magnets form the subjects of the symbols of Figs. 326 to 330. Fig. 326 shows a device whose helix is wired through its own back contact. When a constant potential is applied to this device, the core is energized, attracting the armature and breaking the energizing circuit; the core, thereby, is de-energized, releasing the armature and again closing the energizing circuit, completing the cycle, which is re-

peated continuously so long as the potential is applied. Such a device is the battery buzzer, and the symbol of Fig. 326 is used as a symbol for a buzzer. With a tapper upon the armature and a gong adjacent, it becomes the symbol for a battery vibrating bell. In the symbol of Fig. 327, a yielding spring is attached to the armature to continue the electrical contact during a longer period and thus reduce the rapidity of vibration of the armature. Fig. 328 shows a closed-circuit



Figs. 326 to 330. Vibrator Magnets.

vibrator, since it does not open its helix circuit, shunting its helix instead by its own contact to release its own armature.

Two vibrator magnets which are specialized to secure a long swing to their armatures are shown in Figs. 329 and 330. In Fig. 329, the *Y*-shape lever is assumed to remain inert in either position where it may be left by the tongue, which is attached to the armature and which projects its free end between the branches of the *Y*. With a potential upon the lead-

ing-in wires of the helix circuit of the vibrator, the core is energized, and after the armature has moved through its full swing toward the core, the tongue attached to the armature engages the lower branch of the *Y* and opens the contact of the helix circuit. This de-energizes the core and releases the armature, but the core is not energized again until after the armature has completed its full return swing and the tongue again engages the *Y* at its upper branch, and again moves it to close the helix circuit, completing the cycle, which is thereafter repeated indefinitely.

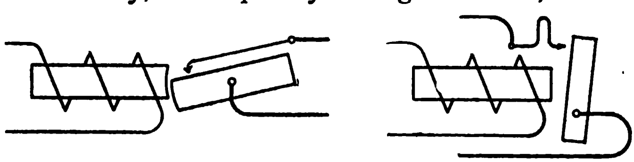
In Fig. 330, the armature, when attracted, pushes up the upper spring of the switch; the vertical locking spring at the right then drops under the upper switch spring and holds the switch open. The armature now must accomplish the full return swing to knock the locking member from under the switch spring before the helix circuit can be closed again. The period of vibration of such a cyclic relay may be made as slow as desired by the provision of a suitable sluggish armature.

Cyclic, or vibrating devices, may have mechanical members directly operated by the armature, as, for instance, the armature in Fig. 266 may be a vibrating armature to drive the ratchet in successive steps. Another method of use involves the connection of some electromagnetic device in series with the vibrator contact, such as the device of Fig. 266, whereby the vibrator acts only as a means for deriving a pulsating current from a constant potential, resulting in the intermittent operation of the controlled device.

LESSON XV.

RELAYS.—ALTERNATING CURRENT. COHERER. SPEECH CURRENT.

Alternating current relays, or relays designed to respond to alternating currents, are shown in Figs. 331 to 339. The distinction which classes an alternating current relay as such, and discriminates between an alternating current relay and a direct current relay is the function of closing the controlled circuit continuously in response to an alternating current passing through the relay helix. It is obvious that a sensitive neutral relay, with quickly acting armature, will re-



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Figs. 331 and 332. Two Relays for Alternating Current.

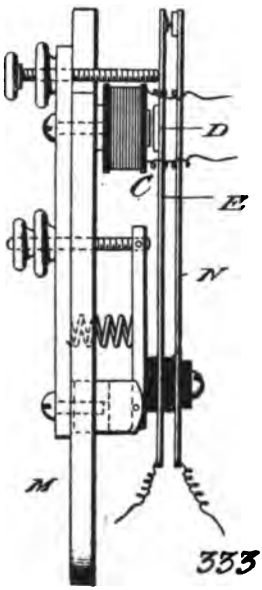
spond to every pulsation or alternation of a current of sufficient strength, but that its armature circuit will be opened for a brief time between the successive alternations. In short, an ordinary relay with quickly acting armature will vibrate its armature in response to an alternating current through its helix. A polarized relay of ordinary construction would not respond to the current waves in one direction, but would respond to the waves in the other direction, thus vibrat-

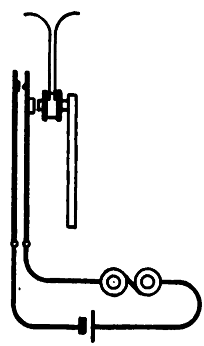
ing its armature at only one-half the speed, or one vibration per cycle instead of one per alternation.

A relay having a sluggish armature will attract its armature in response to alternating current of sufficient strength, and the armature, because of its sluggish movements, will not fall back between impulses sufficiently to permit its controlled circuit to break. This armature will vibrate for every pulsation under the varying degree of magnetization of the relay core, and a yielding contact member is required to retain the closed circuit during the vibration of the armature. The symbols of Figs. 301 to 304 are suitable for alternating current relays, particularly if combined with a yielding front contact such as is indicated in the symbol of Fig. 309. The symbol used most frequently is that of Fig. 304, sometimes modified to show the yielding contact. Figs. 331 and 332 may be taken as types of symbol for the heavy, sluggish armature type of alternating current relay.

Because of the weight of the armature involved, such relays as may be represented mechanically by the symbols of Figs. 331 and 332 usually are not sensitive to weak currents, nor to very rapidly alternating currents. The relay shown in some mechanical detail in Fig. 333 and in symbol in Fig. 334 is designed for operation in response to very small and very rapid currents. In this relay, the permanent magnet *M*, of horseshoe form, carries the pair of electromagnets *C*. The armature *D* is attached to the spring *E*, which is adapted to make contact electrically with the companion spring *N*. Various adjustments are provided.

In the symbol, Fig. 334, the armature contact of this relay is shown connected in series with a battery and an auxiliary pair of electromagnets. When a rapidly alternating current is passed through the helix *C*, the contact of the alternating current relay is kept closed for a sufficient proportion of the time (even if not





Figs. 333 to 334. Relay for Small Currents and Its Symbol.

continuously) to secure a continuous attraction of the armature controlled by the auxiliary electromagnets.

All of the relays thus far discussed have been shown in detail and in symbol as electromagnetic devices controlling their contacts by the operation of a

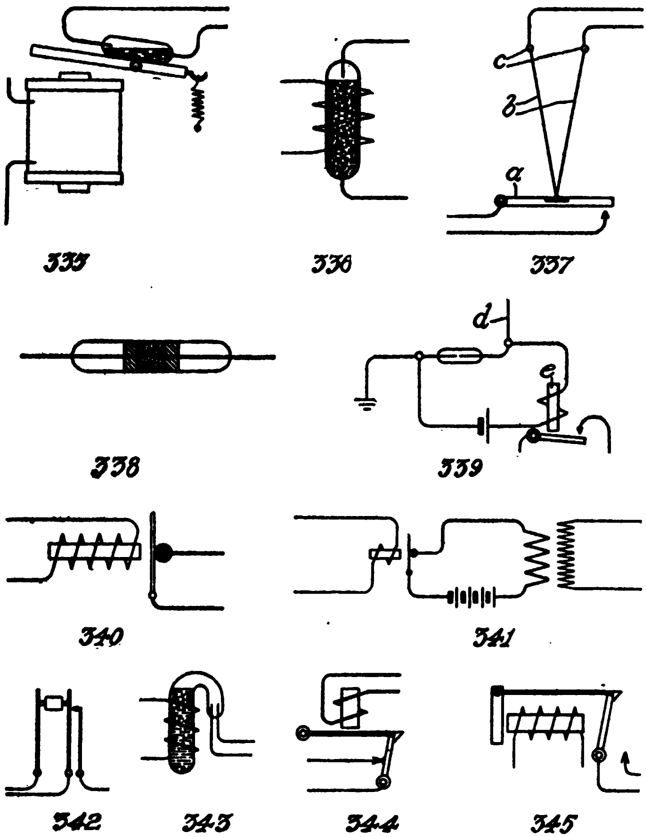
movable armature, the armature either being itself a part of the controlled circuit, or acting to control in turn electrical springs included in the controlled circuit. Figs. 335 to 343 show a few selected symbols typifying relays which involve other methods of controlling the local circuit.

Fig. 335 shows a symbol for a relay in which the contacts are adapted to be closed by a body of mercury which by the inclination of the armature becomes so placed in a sealed glass tube, or cell, that the circuit is opened or closed, as required. With the cell tipped in one direction, the mercury touches both of the wires whose ends are sealed into the walls of the cell, thus completing an electrical path between them. With the cell tipped in the other direction, as in the position shown in the symbol, the mercury runs away from one of the wire ends, and the path between them is broken. The mercury cell is found in many combinations in symbols.

Figs. 336 and 337 show thermal relays. In the symbol of Fig. 336, a sealed mercury cell is represented together with a coil for heating the mercury. By heat from the operating helix, the mercury expands, rises in the cell, and touches the upper wire end. In Fig. 337, the terminals *C* are fixed, and the arm (or armature) *a* is held away from its contact by the wires *b,* which are attached, at one end, to the armature, and, at the other, to the fixed points *c.* When current is passed through the leading-in wires at the top of the symbol, thereby passing through the wires *b,* which form the actuating, or controlling element of the device, the wires

b become heated and expand in length. The expansion of the wires *b* permits the arm to be lowered to touch its contact point, closing the local circuit of the device.

Fig. 338 shows the usual symbol for a coherer. This



Figs. 335 to 345. Unusual Relay Symbols.

device consists usually of a glass tube containing two wire ends slightly separated, the chamber in which the separated ends are held being filled with fine metal granules. The coherer normally has a high resistance, but when a small current passes through it, the resistance is very greatly decreased, due to the tendency of the metal granules to crowd closely together, or to "cohere." An agitator is required in practice to shake the granules apart after the cohering, or controlling, current has ceased, but this detail seldom is shown in the symbol. Fig. 339 shows the coherer connected for receipt of messages by wireless telegraphy. The aerial wire *d* is connected through the coherer to earth. The coherer also carries a small current from battery in series with the relay *e*. Because of the high resistance of the coherer, the relay *e* is not energized, but when any current flows from the aerial wire *d* to earth, the resistance of the coherer is decreased, and the current from the battery becomes of sufficient strength to operate the relay *e*. Upon cessation of current from *d*, the coherer returns to a high resistance, and the armature of the relay *e* accordingly is released.

Telephone relays, voice relays, or speech current relays, are shown in Figs. 340 and 341. Fig. 340 shows the symbol almost universally used for this device, it being borne in mind that almost any form of electromagnet may be placed as the left-hand element of this symbol, and almost any transmitter symbol may be placed as the right-hand element. The vertical element of the symbol is a single diaphragm which is at the same time a diaphragm for the receiving electromagnet and a diaphragm for the variable resistance, or transmitter button, of the

device. In Fig. 341 are shown simple circuits for this device. Weak currents received from the wires entering the diagram at the left pass through the helix of the receiver electromagnet and move the diaphragm. The diaphragm, thus moved, varies the resistance of the carbon button adjacent to it, thus permitting a varying current of considerable strength to flow through the primary of the induction coil. Induced by the heavy primary currents, there flows from the secondary of the induction coil a current, which, if the parts are properly proportioned and adjusted, is of much greater strength than the current originally received.

Circuit controlling devices which may be energized to change a local circuit, but which may not be actuated thereafter to restore the local circuit, are, in substance, in the nature of locking relays. Fig. 342 shows a heat coil device in which the two main springs are held together by a heating element, which also connects them electrically. Current through the two wires leading into the symbol at the left, if of sufficient strength, will so heat the bridging element as to cause it to release the springs from each other, whereupon the circuit between the two springs is broken, and the right-hand main spring moves into contact with the contact spring near it. In Fig. 343, the helix, with sufficient current, will heat the mercury in the bent glass tube until there flows over the bend of the tube a sufficient quantity of mercury to connect electrically the two wire ends which are sealed into the shorter end of the tube. In Fig. 344, the energization of the electromagnet will withdraw the latch which forms its armature, thereby permitting the vertical lever to

fall and to break permanently the electrical circuit of the contact. In Fig. 345, the energization of the electro-magnet will release the drop shutter, and by falling upon the contact point, the shutter will close permanently the circuit of the contact. In each of these tripping relays, the actuating current is unable to reset the device, and the device must be otherwise restored, presumably by the hand of an operator.

Considered with reference to its operation by alternating currents, the device of Fig. 335, if sufficiently closely adjusted, may retain its local contact closed so long as the mercury is agitated. The device of Fig. 336 may be heated as efficiently by alternating as by direct current; this is true also of the device of Fig. 337. The coherer of Figs. 338 and 339 operates in response to rapidly alternating currents, and closes the local circuit continuously while such rapid currents are flowing from the aerial wire. The devices of Figs. 342 to 345 also will operate for alternating currents in the same manner as for direct currents.

The voice-current relay of Fig. 340 produces an alternating current in its local circuit in response to an alternating current in its controlling helix. By this function, it does not fall within the definition of alternating-current relay as above given, although on final analysis, it is the only device of this group of symbols which truly relays an alternating current.

LESSON XVI.

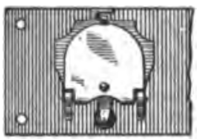
SWITCHBOARD SIGNALS. DROPS. MECHANICAL VISUALS. LAMPS.

The signal used upon the switchboard, and by which the subscriber signals to the operator that attention is desired, is a visual device usually quite silent in its operation. The earliest type was the annunciator drop, a simple shutter held up by an electromagnetic latch. When the latch was operated the shutter was released and attracted attention by the change in its position. It was necessary to reset the device by the hand of the operator. An improvement was made in drops which might be reset electromagnetically, and in mechanical signals which might be displayed so long as the electromagnet remained energized, and which would reset automatically when the energization ceased. The latest type to come into general use is the incandescent lamp.

Figs. 346 and 347 show in mechanical detail front and side view respectively of a switchboard drop of simple type. Figs. 348 to 353 inclusive show symbols used for switchboard drops. Fig. 348 is a full diagrammatic drawing of the essential elements of the drop, as viewed in Fig. 347. This is the symbol usually met. Fig. 351 shows the elements of Fig. 348 more simply drawn, and the symbol of Fig. 352 reduces the side view of the drop to its ultimate simplicity, omitting the armature and reed or latch tongue. Fig. 353 shows a symbol in which the alarm contact is shown.

Figs. 349 and 350 show symbols in which the face view of the drop is taken. The conductors may enter these symbols at any point.

A perspective view of a so-called self-restoring drop is shown in Fig. 354. Such a drop is provided with two independent electric circuits, and usually with two independent electromagnetic systems. One circuit is effective in operating the magnetic latch to trip or release the



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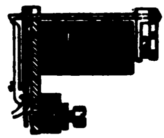

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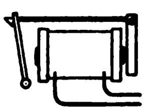

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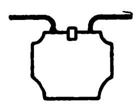

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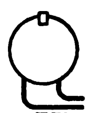

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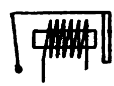

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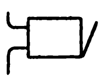

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Figs. 346 to 353. Annunciator Drops.

shutter for display, and the other controls devices adapted to restore the shutter or to return it to its normal position of rest in readiness for a subsequent operation. In the illustration, Fig. 354, a central plate divides the two magnetic systems of the drop and forms the mounting plate for the drop. At the extreme front of the device is a light, thin shutter, hinged at its top edge. Just behind

it is a heavy magnetic armature, hinged at its lower edge. This heavy armature by a small movement can push the light shutter through a large angle for display. The heavy armature of the front end is held by the hook end of a reed attached to a heavy armature upon the rear end of the device. When the rear magnet is energized, the rear armature is attracted, lifting the reed and releasing the front armature, which by a slight movement sets the light shutter to display. By energization of the front magnet, the front armature is attracted, restoring the light shutter, regardless of the energized condition of the back magnet.

Figs. 355 to 357 inclusive show symbols for self-restoring drops. Fig. 355 shows a symbol which may be considered as taken from the drop shown in Fig. 354.

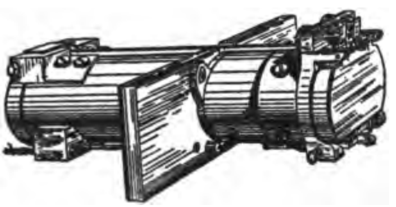
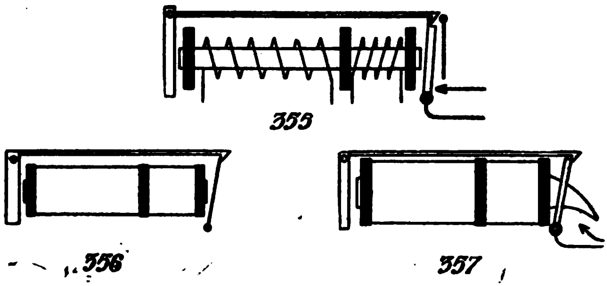


Fig. 354. Self-Restoring Drop.

The detail of latch and armatures, the large actuating coil, the small restoring coil, the detail of shutter and the alarm contact are shown. In Fig. 356 the symbol shown is simpler, but may represent the same device. Fig. 357 shows a symbol for a restoring drop of a slightly different mechanical detail, the shutter being magnetic and the restoring coil being provided with an extension polepiece for attracting the shutter through a wide angle.

Any drop symbol having two coils may be read to represent a self-restoring drop if the circuit conditions so require.

Mechanical detail of another type of self-restoring



Figs. 355 to 357. Symbols for Self-Restoring Drops.

drop is shown in Fig. 358. The operation is simple and the illustration seems self-explanatory.

In Figs. 359 and 360 details of drops are shown which carry the functions of the locking drop. When the front or left-hand coil of the drop is energized the shutter cannot be tripped by the back or right-hand coil. In the upper figure the locking coil holds the magnetic armature

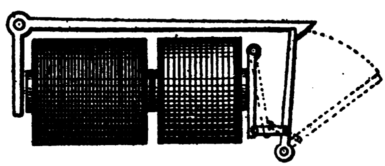
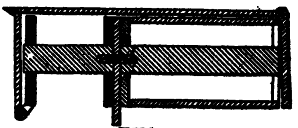


Fig. 358. Another Type of Self-Restoring Drop.

from falling; in the lower picture the locking coil holds the magnetic reed from lifting.

It is required sometimes, and frequently in the case

of very small switchboards where the attendance is not continuous, that the switchboard drop give an audible signal. This leads to the design of a combined ringer and drop, such as is shown in mechanical detail in Figs. 361 and 362. Suggested symbols for such a combined device are shown in Figs. 363 to 365 inclusive. In these symbols the rules for symbol building are observed. Fig. 363 shows a side view symbol of a drop with a ringer gong added, the gong being so positioned that it will be struck by the reed of the drop when the reed is vibrated.



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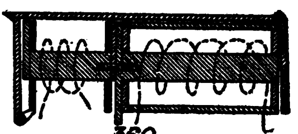

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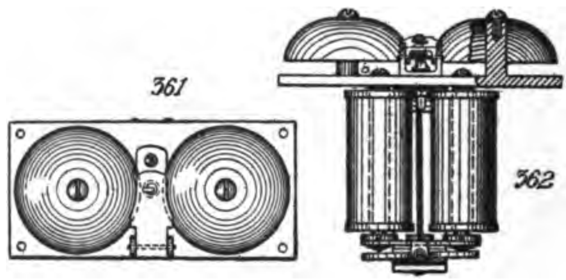
Figs. 359 and 360. Locking Drops.

Fig. 364 shows the front view symbol of a drop with a ringer gong similarly added. Fig. 365, on the other hand, shows a complete symbol for a ringer, and is modified by having a drop shutter added, the ringer reed being extended to form a drop reed as well.

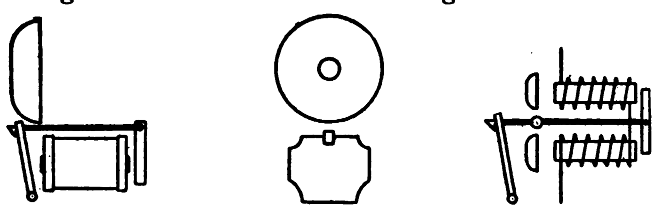
The three symbols here suggested show well how a standard symbol may be modified to indicate a modification or specialization in the piece of apparatus represented by the symbol.

In the class of apparatus called drops, the signal is set when the magnetic latch is operated and the signal



Figs. 361 and 362. Combined Ringer and Drop.

remains set until some action is taken to restore it, whether that action be a manual operation directly upon the drop or the closing of a restoring electric circuit. The term "visual signal" has been used to designate a mechanical device operating to display a signal by changing the position of a movable part of the device, the movable part having two positions, one of which it holds during the time when the core is energized and the other



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Figs. 363 to 365. Symbols for Combined Ringers and Drops.

of which is its position of rest and which position it assumes and maintains during the time when the core is

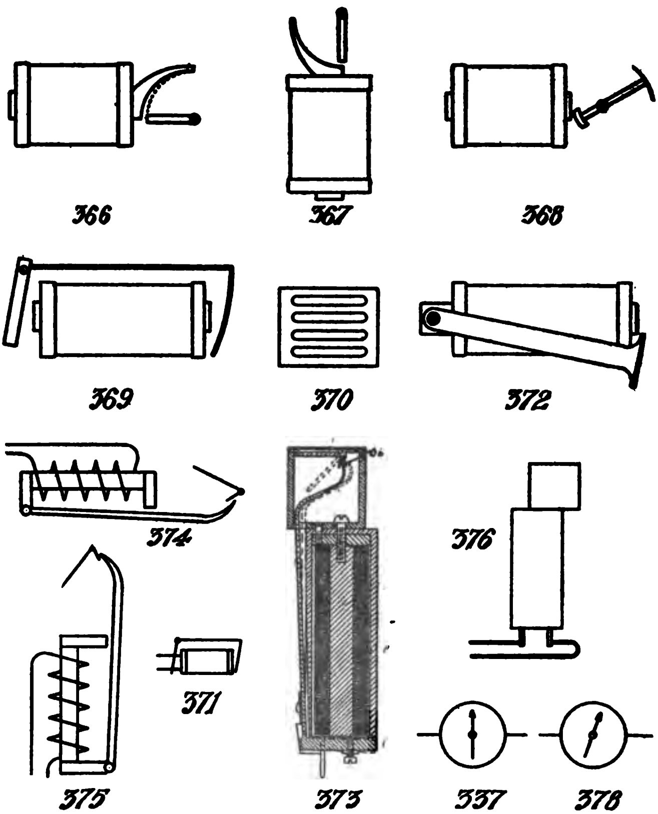
not energized. Such devices are shown in Figs. 366 to 378 inclusive.

The symbol of Fig. 366 is very generally used to represent an electromagnetic visual signal. As the horizontal shutter moves upon its axis, its end follows the dotted line, which is an arc about the axis of the shutter, and therefore the magnetic shutter approaches the extension pole piece, the curve of which is not concentric with the axis of the shutter. The symbol placed as shown in Fig. 266 would represent probably a line signal, or at least a signal mounted in the vertical face of the switchboard, and presumably mounted behind a small window, through which the shutter would be visible when attracted to its upper or vertical position by the magnetization of the core. The same symbol is shown in another position in Fig. 367, presumably in that position representing a signal set in the keyboard or other horizontal shelf.

The symbol of Fig. 368 shows also a movable shutter adapted to be positioned near a small window, in front of which it may swing when the energization of the core causes the weighted end of the pivoted lever to be attracted. When the core becomes degenerized the pivoted shutter is released and the device returns to its undisplayed condition.

The signal shown in Fig. 369 is called the gridiron signal. In this signal the shutter has a very limited movement. It is positioned behind a slotted window or front plate, which is shown in Fig. 370. The face of the shutter is painted with alternate white and black lines. When in its position of rest the white lines are hidden behind the bars of the front plate and the black lines

are behind the window slots. The front plate being painted black, the entire signal presents a black surface to view. When the core is energized, the armature is attracted through a small angle and the signal shutter



366 to 378. Symbols for Mechanical Visual Signals.

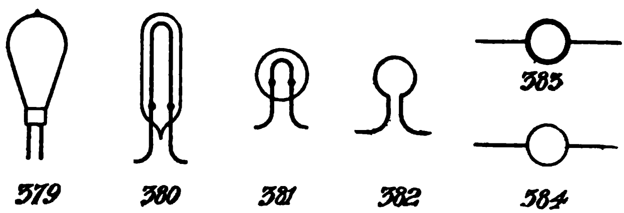
is moved only the width of one line. This brings the white lines of the shutter opposite the window slots and the signal is displayed in white stripes to the operator. Both the side view of Fig. 369 and the front view of Fig. 370 are used as symbols for this type of signal, the symbol of Fig. 380 being used with conductors entering at any point to show its circuit connections. This type of signal forms the basis for the symbol of Fig. 371, a symbol widely used, but with many variations of the magnet spool detail.

The mechanical detail of a visual signal is shown in Fig. 373. The armature is at the bottom of the electro-magnet core; the reed is forced away from the shell of the magnet when the armature is attracted, and a light hinged shutter is struck by the end of the reed and is swung into position in front of a signal window when the armature is attracted, remaining in that position so long as the energization of the armature is continued. This signal is symbolized in Fig. 374 horizontally and in Fig. 375 vertically as for a keyboard signal. The view taken in Fig. 376 is of the outside of the signal shell or mounting case, and lacks sufficient detail to make it a good symbol.

Figs. 377 and 378 show a dial with pivoted pointer, and with leading-in wires for circuit connections. This is the galvanometer symbol as usually accepted. It is used frequently for representing a visual signal. It is entirely noncommittal as to the mechanical detail of the signal required in the circuit. Fig. 377 shows the symbol for a device in the normal position, no current being present in the circuit in which its helix is connected. Fig

378 indicates by the inclination of the pointer that a current is flowing in the helix of the signal. It may be noted that with this signal a double indication is possible, current in one direction moving the pointer in one angle from its normal position, and current in the reverse direction acting to move the pointer to the other angle of inclination.

A set of common symbols used for incandescent signal lamps is shown in Figs. 379 to 384 inclusive. Fig. 379 copies the usual pear-shaped bulb of the common large incandescent lamp used for lighting purposes. Fig. 389 presents the tubular lamp as used generally for lamp



Figs. 879 to 884. Signal Lamps.

jacks in telephone switchboards. Fig. 381 shows an easier symbol for the draftsman, being the symbol of Fig. 380 modified to save space as well as draftsman's time. The symbol of Fig. 382 seems incomplete, but is met frequently. It is a very convenient symbol because so rapidly made in sketching, although it usually assumes the form of Fig. 381 in the finished drawing.

Figs. 383 and 384 are accepted symbols for incandescent lamps on lighting circuits. Fig. 383 represents a lamp not glowing and Fig. 384 represents a lamp glowing. This distinction between glowing lamps and

dark lamps sometimes is indicated by radial lines from the symbols of the glowing lamps, indicating light rays.

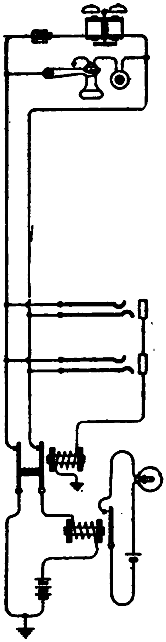


Fig. 385. Line Circuit Using Lamp Signal.

Fig. 385 presents a line circuit using a lamp signal, as an exercise in circuit reading. It may be seen readily by tracing the circuits and assuming proper operation of the different devices of the symbols that the hook switch at the substation controls the glowing of the lamp at the central office, and that by working the hook lever up and down the lamp can be caused to flash again and again. It may be seen also that upon the insertion of a plug in either of the multiple jacks, in response to the lamp signal or for purpose of calling the subscriber, current must flow from the body of the jack to earth through the "cut-off" relay, the upper of the two relays, which by operation of its armatures will remove the lamp from control of the substation hook switch so long as the plug remains in the jack.

LESSON XVII.

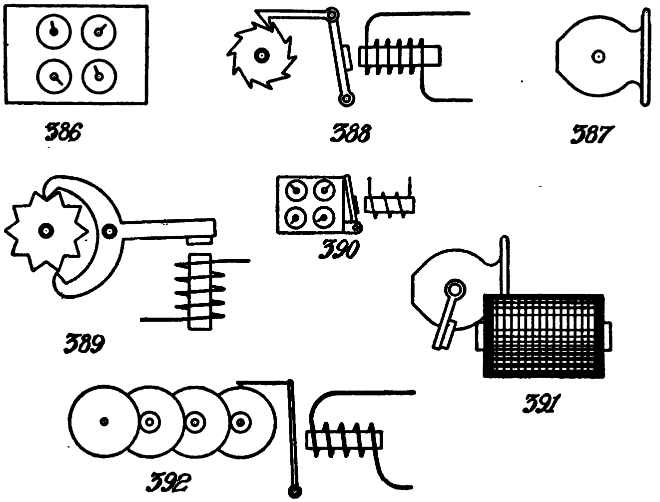
MESSAGE REGISTERS. POWER PLANT APPARATUS.

Telephone registers usually have the function of recording the number of calls or conversations originating at a substation, although the register may be either at the substation or at the central office. The symbols used for registers consist wholly or in part of a representation of the counting train, or of the dials and the casing which contains them. This simplest form, without circuit connections, gives the symbols of Figs. 386, showing face view of the dials, and 387, showing side view of the case of a well known type of counting device. When the counting train of the register is electromagnetically operated, the electromagnet usually is shown with its circuit wires in connection. The symbol of Fig. 390 repeats Fig. 386 with the addition of electromagnet and armature, while the symbol of Fig. 391 bears the same relation to that of Fig. 387. The electromagnet with armature and ratchet shown in Fig. 388 is a symbol going into the detail of operation of the first wheel of the counting train; this symbol sometimes is amplified to show further wheels, similar to the wheels of Fig. 392. In Fig. 389, the star ratchet is driven by the teeth of the double pawl alternately. The ratchets shown have ten teeth, indicating their association with the usual decimal system of numeration. In Fig. 392 the draftsman has simplified Fig. 388 by neglecting to draw the teeth upon the ratchet wheel.

In the circuit drawings of a complete telephone ex-

change or system, the power apparatus, or apparatus carrying the heavier currents of the common sources of energy of the central office, will be found to be represented by appropriate symbols, just as are the items of apparatus which are specifically telephonic in nature.

Symbols for motors and generators of divers types are shown in Figs. 393 to 412. In Figs. 413 to 417 are

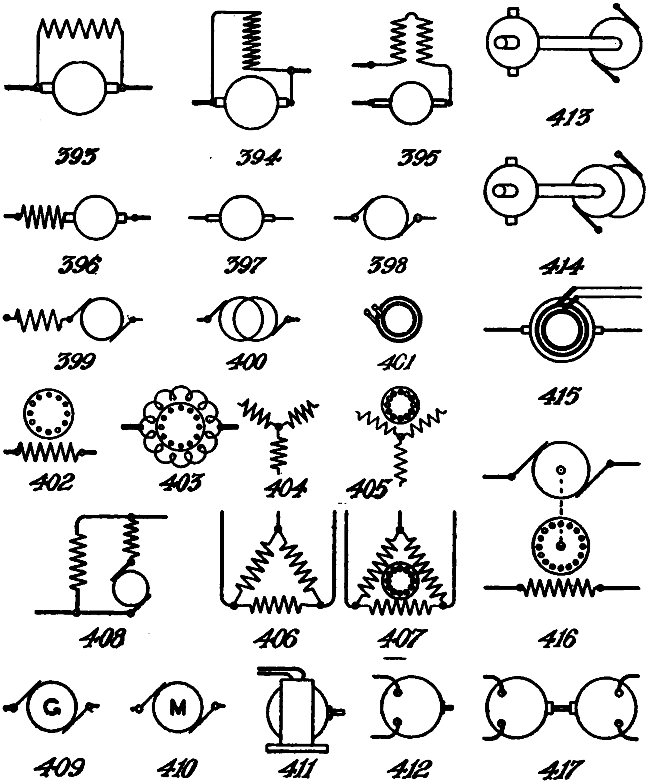


Figs. 386 to 392. Symbols for Call-Registers.

shown symbols for pairs of machines or machines having the double function of motor and generator at the same time, called variously motor-generators, dynamotors or rotary transformers. In symbols for generators and motors for direct currents, there is an apparently arbitrary distinction between symbols for

motors and symbols for generators which is very widely observed. This distinction is the detail of the brushes. It should be noted that a direct current motor and a direct current dynamo are built alike. A motor may be run as a dynamo or a dynamo may be run as a motor, if desired, the machine being adapted to convert electricity into motive power or motive power into electricity, receiving either form of power that may be supplied to it and in turn supplying the other form. With this point in mind, it is clear than any distinction which exists between the symbol for a motor and the symbol for a dynamo must be a purely arbitrary distinction. The point in question may be observed by comparing Figs. 397 and 398. The former, with the radial brushes, is accepted as a general symbol for a direct-current motor; the latter, with the tangent brushes, is accepted as a general symbol for direct-current dynamo or generator. These symbols represent end view of armature or commutator only, and this element is accompanied sometimes by a representation of the field winding of the machine to indicate the shunt, series or compound nature of the field winding. Comparing Figs. 396 and 399, it is found that a series connected machine is represented in each instance, the machine represented in the symbol of Fig. 396 being a motor and in Fig. 399 a generator or dynamo, the distinction being based upon the detail of brush symbol. A series motor is represented also in the symbol of Fig. 395, and shunt motors are represented in the symbols of Figs. 393 and 394. A generator with compound field coils is shown in Fig. 408.

Motors and generators may be distinguished by the further means of adding the letter *M* or *G* to a simple



Figs. 393 to 417. Symbols for Motors and Generators.

symbol, as illustrated in Figs. 409 and 410, the same symbol being used in both instances.

In alternating current generator symbols, the two

collector rings and their brushes usually are adopted to represent generators of two-phase current; such symbols are shown in Figs. 400 and 401. A similar symbol consisting of three rings and three brushes doubtless would represent a three-phase alternating current generator. However, the three-phase generator usually is represented by a showing of the three windings of its armature, connected either in star or delta as circumstances may dictate, or at the option of the draftsman; such symbols are shown in Figs. 404 and 406.

Motors driven by alternating currents usually have no brushes, and the symbol of Fig. 397 or its derivatives would be inappropriate. A characteristic of the induction motor for alternating currents is the squirrel-cage armature, which therefore offers a distinguishing feature for a symbol for all such motors. Such an armature alone with leading-in conductors might well serve for a symbol for an alternating current motor, but it is commonly used in connection with a representation of field coils. Fig. 402 shows a symbol for two-phase current motor, the two line conductors being attached to the field coil and the armature unconnected, as is the true service condition of the motor. Fig. 403 shows a symbol presenting a different arrangement of field coil. Fig. 405 shows a symbol for three-phase motor with star connection, and Fig. 407 shows a symbol for a similar motor with delta connection of its fields.

Figs. 411 and 412 show the case of the motor only; presumably Fig. 411 is a side view and Fig. 412 is top

view. Either might be direct current motor or two-phase alternating.

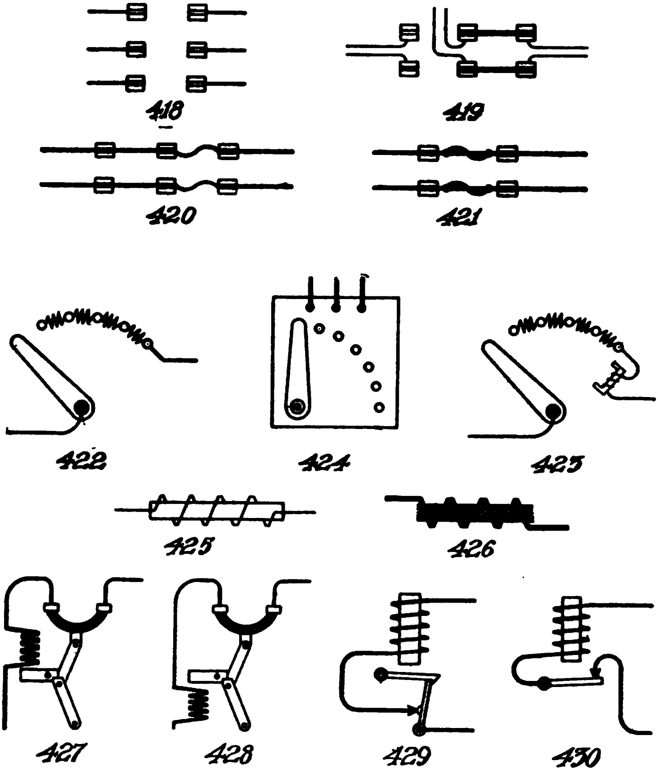
The combination machine of Fig. 413 is a direct-current motor driving a direct-current generator, or a so-called rotary transformer. The symbol indicates that the two machines are mechanically connected by having their commutators on the same shaft. The symbol of Fig. 414 shows a direct-current motor driving an alternating-current generator, and Fig. 415 presents another symbol for the same apparatus.

In Fig. 416, a symbol is presented which shows the alternating-current motor directly connected to a direct-current generator. In Fig. 417 a double symbol of Fig. 412 is presented. It may be assumed that one of the devices is a motor and the other a generator, but which is which and whether alternating or direct current devices must be determined by the associated circuits of the diagram in which this symbol has appeared.

Switches for carrying heavy currents, such as are associated with motors and generators, usually take the symbols of Figs. 418 to 421. Fig. 418 shows a three-pole single-throw switch; Fig. 419 shows a two-pole double-throw switch. Fig. 420 shows a two-pole single-throw switch with fuses mounted either as a part of the switch, or adjacent to it. In Fig. 421 it is clear that the fuses are mounted upon the blades of the switch. A power switch symbol is shown also in Fig. 222.

A large direct-current motor is started by a variable-resistance device called a starting box or rheostat.

This device seldom varies in symbol from the symbols of Figs. 422, 423 and 424. Fig. 422 shows the movable



Figs. 418 to 480. Symbols for Power Switchboard Apparatus.

arm and variable resistance; Fig. 423 shows in addition a holding magnet for restraining the arm at the right while current flows through the device; Fig. 424

shows the mounting of the electrical elements without showing the elements themselves, and shows also the three leading-in wires, for such a starting box usually has three binding posts.

The talking circuit of a common battery or central energy telephone exchange having but one battery is connected to the battery at all times, and when the charging generator is connected with the battery the sound of the commutator of the generator sometimes may be heard upon the telephone lines. To prevent this sound from reaching annoying proportions, choke coils are used; symbols for choke coils are shown in Figs. 425 and 426.

The power circuits, and particularly the charging circuit of the main batteries, are provided with devices for opening the circuit in case the current carried becomes either too large or too small. Underload circuit breakers are shown in symbol in Figs. 427 and 430; overload circuit breakers are shown in Figs. 428 and 429. The symbols of Figs. 427 and 428 are of later origin, but are well authorized. In each, a circuit is held closed by a brush sustained by a toggle, the toggle being held by a latch lever which is the armature near the coil or helix shown at the left of the symbol. In the case of Fig. 427, the helix holds the armature to retain the toggle latched and when the current becomes an underload the latch will be released; in the case of Fig. 428 the helix does not attract the armature during normal currents, but an overload of current will pull down the armature and unlatch the toggle.

Figs. 429 and 430 show older symbols for circuit

breakers. In Fig. 429 the overload circuit breaker will break its circuit when the current becomes strong enough to lift the latch which is the armature of the magnet. In Fig. 430, the underload circuit breaker will break its circuit whenever the current through its helix becomes so low that the armature is released.

LESSON XVIII.

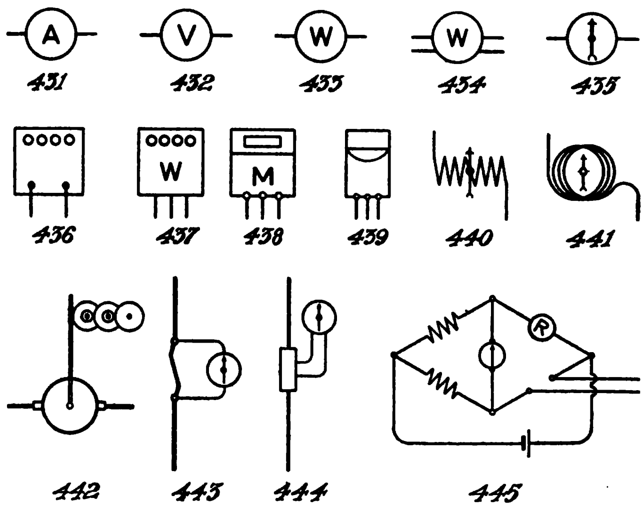
MEASURING INSTRUMENTS. RECTIFIERS. PROTECTORS.

The usual symbol for a measuring instrument upon the power circuits of a telephone exchange is simply a circle within which is written a letter to indicate the nature of the meter. Fig. 431 shows symbol for an ammeter, Fig. 432 a voltmeter, Fig. 433 a wattmeter. In the wattmeter symbolized in Fig. 434 there are four leading-in wires, two for bridging or potential wires and two for series or current wires. The two circuits of a wattmeter may be cared for by three wires; see symbols of Figs. 437, 438 and 439. In Figs. 436 to 439 a case with dials is indicated. The presence of dials or their indication, or of the type of case here shown, indicates that the meter is an integrating meter, whereas the meters symbolized in Figs. 431 to 434 are presumably meters for instantaneous readings only. The meter of Fig. 436 may be an integrating meter recording in any unit; Fig. 437 shows a wattmeter as indicated by the label *W;* Fig. 437 again is a meter for any unit, the label *M* merely emphasizing its identity as a meter. The symbol of Fig. 439 is a front view of a common type of integrating meter case, and is widely used, principally for wattmeters.

In the symbol of Fig. 442 an integrating meter is shown in a symbol which takes note of its electrical characteristics rather than of its dial or case. An integrating meter is essentially a motor driving a record-

ing train of dials, and in the symbol of Fig. 442 the motor symbol is embodied in connection with a worm and gear-train movement the wheels of which are presumably dials.

The proper interpretation of Fig. 435 is that it is a symbol for a galvanometer; but inasmuch as a voltmeter is a galvanometer, and an ammeter is a gal-



Figs. 481 to 445. Symbols for Measuring Instruments.

vanometer, etc., the symbol has the possibility of rather erratic application. Galvanometer symbols are shown also in Figs. 440 and 441, the showing in each instance being that of a helix and a pivoted needle.

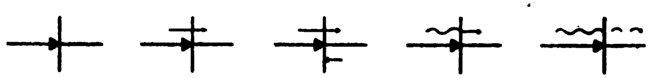
Figs. 443 and 444 show in each instance an ammeter and its shunt. In each a reflecting galvano-

meter symbol similar to that of Fig. 435 is connected to the terminals of a resistance which forms a part of the circuit in which is flowing the current to be measured by the ammeter. In Fig. 443 the resistance is shown by the usual irregular line between two terminals.

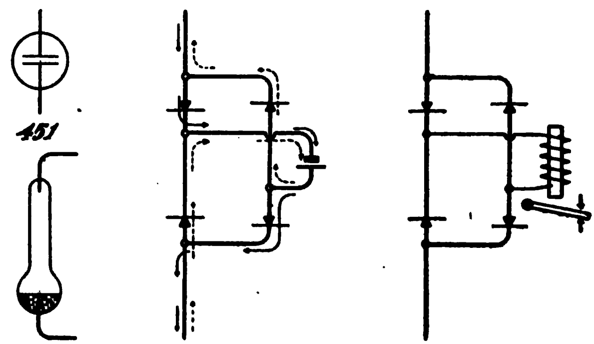
Fig. 445 shows the usual symbol for a complete Wheatstone bridge, a measuring instrument whose symbol will be encountered in diagrams pertaining to telephone testing rather than to diagrams of telephones or central office circuits. In this diagram, the two resistances at the left are the ratio arms of the bridge, seldom shown adjustable, although usually so in practice. The circle *R* is an adjustable resistance, and in the middle of the figure is a galvanometer, which in this case is merely a current detector rather than any kind of calibrated meter.

The current rectifier is an instrument usually associated with the power board and the charging of small storage batteries. Fig. 452 shows a symbol for the mercury vapor rectifier. This is substantially a picture of the device, which is a glass tube containing two conductor terminals and a quantity of mercury. Fig. 451 shows two conductor terminals within some kind of enclosure, and may represent either the mercury vapor rectifier or some form of electrolytic rectifier; it differs from a battery symbol in that its two electrodes are alike. Further, the symbol of Fig. 446 is used, sometimes accompanied by the light arrow as in Fig. 447, the light arrow denoting the direction in which current is permitted to flow by the device. It

would seem that the addition of a short arrow as shown in Fig. 448 would make the symbol entirely self-explanatory, since an arrow near a conductor is an accepted symbol to indicate current flowing in the conductor. The symbol of Fig. 448 therefore represents a device which permits current to flow in the one direction but stops the current at the vertical line when a



446 447. 448 449 450



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452 453 454

Figs. 446 to 454. Symbols and Circuits for Rectifiers.

tendency to flow in the reverse direction is manifested. Further suggestions are offered in Figs. 449 and 450. In Fig. 449 the arrow indicates in its waved portion that an alternating current is flowing in the adjacent conductor, and after passing the rectifier the arrow becomes straight, indicating that a direct current or current in one direction only is flowing. In Fig. 450

the symbol indicates that one phase of an alternating current has been suppressed.

Fig. 453 shows circuit connection for a set of four rectifiers in connection with a battery cell and an alternating current wire. The vertical wire at the left of this figure is a wire carrying an alternating current. The four rectifiers are shown according to the symbol of Fig. 447. The phase of the alternating current which flows from top to bottom in the drawing finds a path from the top of the figure through the left upper rectifier, thence to the right and downward through the battery cell, downward through the right lower rectifier, to the left and then to the bottom of the diagram. The remaining phase of the alternating current, flowing from bottom to top in the drawing, finds a path from the bottom of the figure, through the left lower rectifier, thence upward, to the right and downward through the battery cell, to the left and upward through the right upper rectifier, again to the left and then to the top of the diagram. It is seen thus that both phases of the alternating current pass through the battery cell in the same direction, downward, owing to the action of the rectifiers, and this cell, presumably a storage cell, therefore may be charged properly by the alternating current flowing in the main vertical wire.

In Fig. 454 the relay shown may be taken in connection with the four rectifiers shown to serve as an alternating current relay. The current through the relay thus connected is a series of impulses in the same direction, instead of in constantly alternating directions as when directly connected in the main vertical wire.

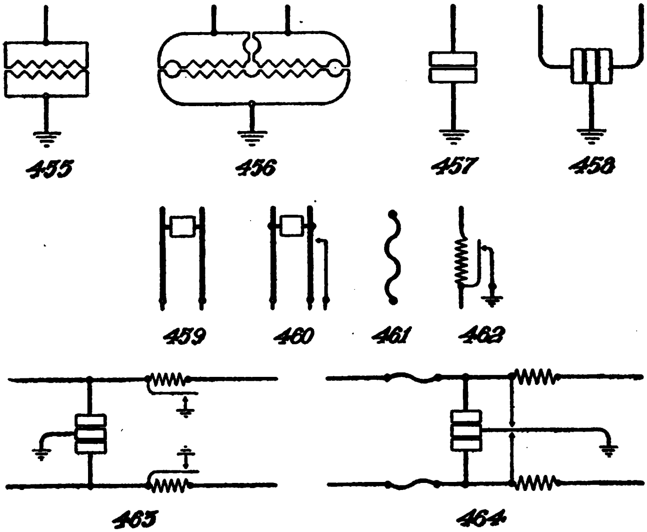
Protectors such as are used on telephone lines are shown in symbols of Figs. 455 to 464.

Fig. 455 shows the simplest form of saw-tooth or open-space lightning arrestor. This consists essentially of two metal plates having points near each other, one of the plates being connected to earth and the other to the telephone line wire. Its theory of action is that, because of the inductance of the elements of the telephone apparatus, any charge of electricity acquired from a lightning flash will jump the narrow gap between the arrestor points and thus pass harmlessly to earth rather than traverse the windings of the magnets of the telephone.

In Fig. 456 a device of similar nature is shown, elaborated for two line connections and a ground plate, and for switching plugs. When a conducting plug is inserted in the opening between the circular notches at the left end of this device, the left wire of the line wires is connected to earth; the same is true of the remaining line wire when a conducting plug is inserted in the circular opening at the right end. By inserting such a plug in the center of the device, both lines are connected to earth, while a plug inserted in the opening between circular notches near the top of the symbol and between the two line plates will connect the line wires together without connecting them to earth. Such a device serves at the same time as a lightning arrestor and as a switching device for cutting out the telephone or short circuiting it during storms, or for switching the line conductors and the earth conductors for testing purposes.

A more efficient open-space lightning arrestor is formed of two carbon blocks spaced near each other; this is the subject for the symbols of Figs. 457 and 458, which show such devices for one and two line conductors respectively.

Fig. 459 shows symbol for a heat coil, or sneak



Figs. 455 to 464. Symbols for Protectors.

current protector. The two vertical springs have a normal tendency to spring apart, but are held together by the heat coil between. This heat coil is constructed with a resistance element such that heat will be generated in accordance with the volume of current passing, and it is so constructed further that when a pre-

determined degree of warmth is reached it will release the vertical springs, which then separate and break the circuit. In Fig. 460 a contact is added forming an alarm switch by which an alarm is rung when a heat coil is operated.

The heat-coil symbol of Fig. 462 takes note of the electrical details of the heat coil and alarm switch, ignoring the casing or outward appearance of the device.

Fig. 461 shows the accepted symbol for a fuse.

Figs. 463 and 464 show the complete protective apparatus of a telephone line, using accepted symbols. In Fig. 463, the heat coils are represented by separate complete symbols; in Fig. 464, the contacts controlled by the heat coils are associated with the same earth conductor that serves the carbon arrestor. Fig. 464 also shows a line equipped with fuses. The entire protective apparatus of either of these figures is built together mechanically, and the figures may be taken to represent single symbols for a complete line protection rather than diagrams composed of many individual symbols.

LESSON XIX.

ELECTRICAL UNITS. ADJUSTABLE DIMENSIONS. POTENTIALS. RESISTANCE.

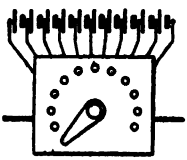
The draftsman in his work of making telephone circuit diagrams has been called upon often to show in the drawing some representation of electrical dimension. Simplest and most frequently of all it may be a matter of resistance and potential, ohms and volts; again, it may be inductance, capacity or current, henries, farads or amperes.

The only showings of absolute values in the circuit diagram, expressed in standard units of measurement, have been made by the use of figures set near the symbols for the different parts upon which the value is to be indicated. Relative values, wherein the diagram indicates that the dimensional value of one unit of apparatus is greater than the dimensional value of another unit of apparatus of similar nature, have been expressed frequently by differences among the symbols of the diagram, the symbols used being so modified for the different parts of apparatus that the interpretation of the distinction becomes manifest at once.

Symbols for potential or voltage are given in Figs. 10 to 16, inclusive, and in Figs. 10 and 11 are shown two symbols representing potentials which differ from each other. As many different relative potentials as may be required for the purpose of any

diagram may be represented by the number of times the cell-symbol of the referred form is repeated in the representation of each voltage or unit of apparatus.

Symbols for adjustable potentials are not met frequently. Two symbols which have been used are presented in Figs. 465 and 466, each being in substance such a grouping of simple units as will effect the application to a circuit of a potential which may have a value adjustable at will. Fig. 465 shows a multipoint switch associated with a main circuit leading out at right and left, to which the potential is to be applied,



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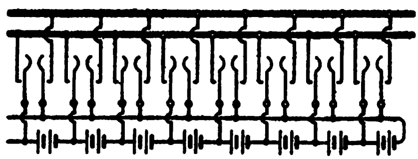

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Figs. 465 and 466. Symbols for Adjustable Potentials.

and a set of battery cells leading presumably to the contact points of the switch, whereby any desired number of cells may be included in the circuit of the main leading-in wires, by the position of the lever of the switch. Obviously, such a symbol may take a form analogous to that of the symbol of Fig. 472 or Fig. 476, the cell-symbol of the battery being substituted for the resistance symbol in its several parts.

In Fig. 466, a series of battery symbols is associated with a series of switch symbols. Since the operation of any two of the keys simultaneously would shortcircuit a portion of the battery, it becomes evi-

dent that but one key may be operated at any time, and since each key represents a different potential which may be applied to the main circuit at the top of the symbol, the entire figure may be regarded as an integral symbol indicating that there may be applied to the conductors at the top of the figure a potential of any desired value obtainable from the batteries at the bottom of the figure. Any potential applied from the battery to the conductors at the top of the figure may be readjusted to a new value by releasing the key used and operating another key corresponding to the new value desired.

A possible symbol for adjustable potential is the symbol for the dynamo, with a showing of a field coil (Figs. 393, 394, 395) adjacent to the dynamo symbol, with a battery (Figs. 10 to 16) and rheostat (Figs. 472 to 478), the battery and rheostat being in series with the field coil in a local circuit.

Resistance symbols commonly appear in the forms shown in Figs. 467, 469 and 470. Fig. 467 may be taken as representing a side view of a series of helical turns; Fig. 469 represents a perspective view of the same; in Fig. 470 the key to the symbol is the letter *R*, an abbreviation for the word *resistance*, an abbreviation which sometimes is found *Res.*

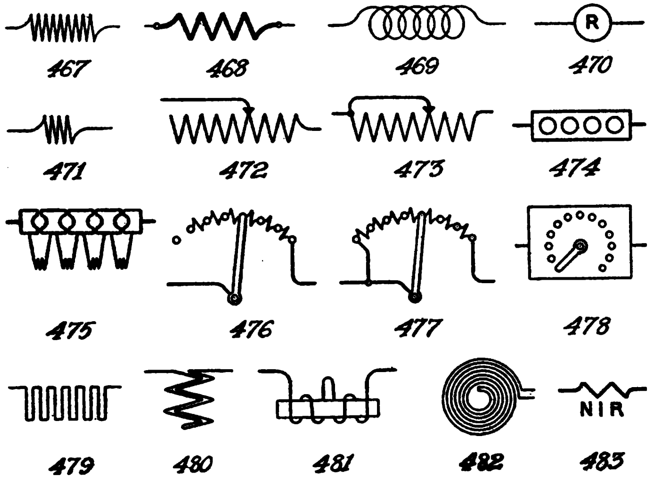
Relative resistances are represented either (*a*) by a noticeable difference in the number of turns represented, or (*b*) by the thickness of the line representing the conductor, or by both methods combined. Fig. 467 compared with Fig. 471 will show a difference in

resistance value according to the first principle; Fig. 471 compared with Fig. 468 will show a difference in resistance value according to the second principle; Fig. 467 compared with Fig. 468 will show a difference in accordance with either or both of the principles, and usually both principles are observed in circuit diagrams.

The adjustable resistance or rheostat has its full quota of symbols in endless variation. Usually such a symbol comprises a showing of resistance and of switch; see Figs. 475, 476 and 477. All detail of switch sometimes is omitted, abandoning all mechanical features and making a showing of electrical features only; see Figs. 472 and 473. On the other hand, the showing of resistance sometimes is omitted entirely, a showing of a switch alone being made; see Figs. 474 and 478. Motor starters (see Figs. 422, 423 and 424) usually involve the principles of symbols for adjustable resistances.

A distinction between the symbols of Figs. 472 and 473 exists in the attachment of the conductor leading in from the left. In the former figure, the conductor is not attached to the resistance element of the symbol except by its adjustable contact; in the latter, the conductor is permanently attached to the end of the resistance element, and in addition has its adjustable contact with that resistance. In Fig. 473, the value of the resistance may be adjusted from zero to the maximum for which the apparatus is designed, but the circuit can not be opened by any setting. In the device symbolized in Fig. 472, the circuit may be

opened by moving the adjustable contact beyond the left-hand end of the resistance element. In Figs. 476 and 477 a similar distinction exists. A contact point is shown in Fig. 476 in isolated position at the left of the arc of resistance contact points, to which isolated point the contact lever may be moved when it is desired to open the circuit through the device. In Fig. 477, the



Figs. 467 to 483. Symbols for Resistances, Simple, Adjustable and Non-Inductive.

circuit is closed at all times, and may not be left open, even by accident or oversight. Each type of rheostat, therefore, has its advantages, and the distinction may bear weight in the study and solution of the diagram in which the symbol is found.

Fig. 475 shows a resistance in sections, any sec-

tion of which may be short-circuited by a conducting plug inserted between the contact plates forming the row of elements across the top of the symbol; in this symbol also the circuit cannot be opened by intent or accident.

The symbol of Fig. 474 is a simplified showing of that of Fig. 475. The symbol of Fig. 478 is a simplified showing of those of Figs. 476 and 477; as to which one of them in particular, the symbol is noncommittal. Fig. 474 is met frequently; its wide popularity probably is due to the general use of plug switches for the variable resistances of Wheatstone bridges and similar testing devices.

Resistance without inductance, usually termed *non-inductive resistance,* is represented in the symbols of Figs. 479 to 483, inclusive, the absence of inductance being emphasized in those symbols.

Resistances not composed of long wire, nor of long strips of conducting material, usually are considered non-inductive. Such resistances are ammeter shunts, carbon rods, telephone transmitters, extremely short wires, the planet earth, silicon crystals, metals in mass, etc.

To obtain a non-inductive resistance by means of wire, it is required that the current shall be given a path through the wire in such direction that the total of its passage in one angular direction about a real or imaginary helix core shall be equal to the total of its passage in the opposite angular direction. A resistance unit so constituted is termed a non-inductive resistance. It is prepared usually by joining the ends

of two similar wires and then winding the two together upon a core or spool. The symbols of Figs. 480, 481 and 482 are based directly upon this method of manufacture.

Fig. 480 shows a side view of the double helix which this method of manufacture produces; the wires are joined at the bottom and the helix is formed by winding upward, the two outer ends of the wires being the leading-in wires or terminals of the complete non-inductive resistance. Fig. 481 shows the same structure with a view of the core, the wires being shown progressing each from the middle toward the ends; they may as well and even more logically progress from one end to the other of the core, giving a junction point at one end of the core and offering two free terminals at the other. Fig. 482 represents an end view of a helix begun with joined wires and terminating at the outside of the coil with two free wire ends.

The abbreviation *NI* adjacent to a resistance symbol indicates that the symbol is to be read as representing non-inductive resistance, while the abbreviation *NIR* adjacent to any symbol has a similar interpretation; this is indicated in Fig. 483.

The symbol of Fig. 479 appears to be purely arbitrary. It is easy for the draftsman's pen, and it is recommended by the United States Patent Office for use in diagrams forming parts of applications for patent. For these two reasons, the symbol of Fig. 479 is likely to have an extended use, despite the weakness resulting from its lack of inherent meaning.

For relative dimensions and for adjustable dimension, the principles discussed above with reference to resistances in general will be found to apply to symbols involving non-inductive resistances.

LESSON XX.

INDUCTANCES. DIFFERENTIALS. CAPACITIES. THE ARTIFICIAL LINE.

Resistance with inductance sometimes is embodied in a structure or circuit solely for the feature of its inductance. In such an instance, the inductance being the essential feature of the apparatus, the symbol emphasizes the inductive nature of the apparatus.

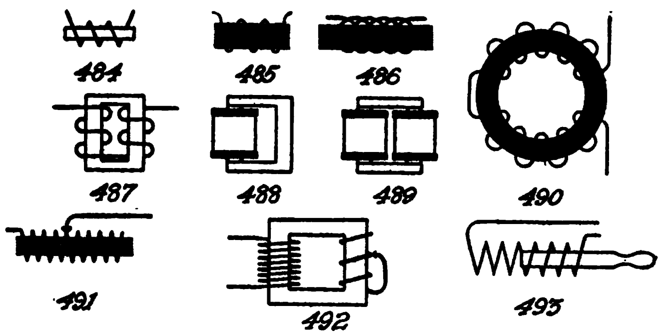
Figs. 484 to 493, inclusive, show symbols for resistances having inductance, or it may be said properly that the symbols represent inductances.

Fig. 484 shows a core and a wire wound about it; this distinguishes from the simple resistance symbol of Fig. 467 by showing positively the fact that the wire is wound upon a core. Such an inductance is in form an electromagnet. Fig. 485 shows a core composed of a bundle of small wires; this type of core is used to increase the inductance of a helix, and a symbol showing such a core therefore emphasizes the inductive nature of the helix as compared with the simple electromagnet. Fig. 486 shows a similar construction, but varies the type of helix drawn upon the core.

Closed-magnetic-circuit inductance units are shown in the symbols of Figs. 487 to 490, inclusive. Fig. 487 shows a closed-circuit symbol of a type easily drawn. Fig. 488 shows side view of an electromagnet spool with horseshoe keeper to close the magnetic circuit. Fig. 489 shows a pair of electromagnet spools

with keepers across both ends to close the magnetic circuit. Fig. 490 shows the toroidal inductance unit using the closed core of small wires, the winding being shown in skeleton and showing the arrangement of turns; such a coil may have the two halves of its winding connected either cumulatively or differentially magnetic, the inductance values of the unit being variant in the two cases.

Adjustable inductances are shown in the symbols



Figs. 484 to 493. Symbols for Inductances, Simple and Adjustable.

of Figs. 491, 492 and 493. In the device symbolized in Fig. 491, the inductance value of the device depends upon the number of turns which the current makes about the core, and this number may be varied by moving the adjustable contact. In the device of Fig. 492, the closing of the secondary or right-hand winding varies the inductance of the unit as manifested upon the primary or left-hand winding; by moving the adjustable contact of the secondary, the inductance of the primary winding is varied and adjusted.

In the device of Fig. 493, there is symbolized a unit which is adjustable by changing the position of the core within the helix. When a greater amount of iron is introduced into the open end of the helix, a greater value is given to the inductance of the unit as manifested in its helix. That the core is movable with reference to the helix is manifested by the shaping of the end to form a handle by which it may be moved. The attachment of levers to the core also would indicate a movable core and therefore a variable or adjustable inductance.

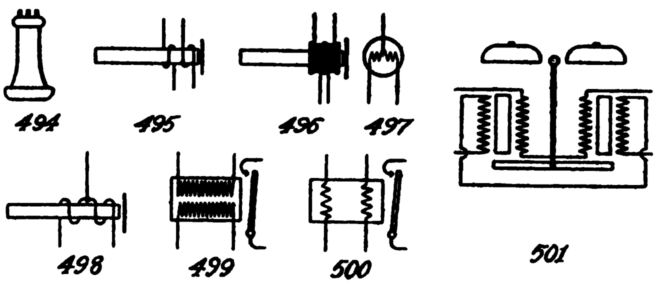
Relative values of inductance in separate symbols of a diagram may be indicated by variant numbers of turns about similar cores, or by variant positions of cores in similar helices such as that of Fig. 493.

The matter of differential and cumulative inductances, where a plurality of windings upon a single core are involved, has been discussed in connection with Figs. 258 to 264, inclusive.

Differential inductances appear frequently in almost any type of electromagnetic apparatus. In such instances, where current through one winding is required to neutralize the inductive effect of current through another winding, the two windings usually are shown as nearly equal in appearance as possible, although this has been by no means an absolute rule. A few symbols for differential units of apparatus are shown in Figs. 494 to 501, inclusive.

Fig. 494 indicates by the three terminals at the top of the receiver that there are two windings, one terminal being common to the two; whether the coils are

differential upon each other at all times, or under certain conditions, the diagram reader is left to surmise, or to assume some condition which will be in harmony with the remainder of the diagram. In Fig. 495 the two coils of the telephone receiver are drawn and their inductive relation is disclosed by the direction in which the wires pass around the core. In Fig. 496 the two windings are indicated by the septum between the spools, but the direction of the turns around the core must be assumed or gleaned elsewhere in the diagram



Figs. 494 to 501. Symbols for Inductances Differentially Related.

of which this symbol forms a part. Fig. 497 also shows a symbol for a "split-wound" element of some sort, probably a "head telephone" or operator's small receiver. Fig. 498 shows a receiver symbol similar to that of Fig. 495, but with a "split" winding instead of two independent windings.

Figs. 499 and 500 show differential relays. In each of these relays the two windings which are supposed to neutralize each other are shown as nearly alike as the skill of the draftsman would make them,

but the direction upon the core is not shown. The free-hand windings of Fig. 500 make that symbol an easy one to draw. Are not both of these symbols representative of relays with a repeating-coil function? The diagram in which the symbol was found must answer the question. The symbol in itself neither discloses this detail nor denies it.

Some fundamental principles in reading inductances may be studied in connection with Fig. 501. This symbol represents a polarized telephone call bell, each of the magnet spools of which is double-wound. The requirement of such a call bell when to be actuated by ringing current is that the upper end of one core shall be magnetically positive at any time and at the same time the upper end of the other core shall be magnetically negative. Taking the upper wire of the two wires entering the symbol of Fig. 501, it is seen that the circuit progresses downward along the left-hand core and upward along the right-hand core. The indication is that the entering end of one helix is the same in magnetic polarity as the entering end of the other helix, therefore that that magnetic polarity which is found at the upper end of the left-hand helix is the same as that found at the lower end of the right-hand helix, giving thus the proper magnetic condition for the operation of the polarized ringer. Taking the lower wire of the two wires entering the symbol, it is seen that the circuit of this wire progresses upward along the left-hand core and then downward along the right-hand core. Assuming that the magnetic polarity of the entering end of the helix of the second circuit

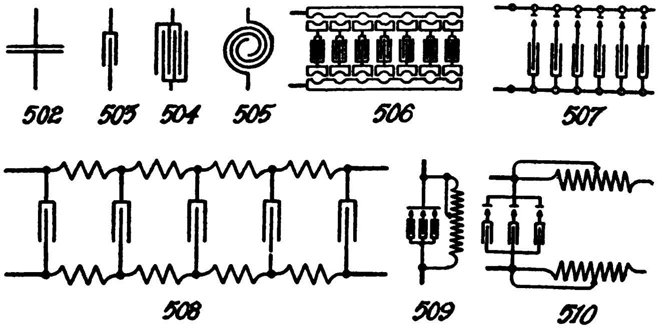
is of the same magnetic polarity as the entering end of the helix of the first wire, it will be seen also that with current passing from left to right along both of the wires of the symbol the magnetic polarity produced by each winding in either core will be opposing that produced by the remaining winding of that core.

The ringer of the symbol of Fig. 501 therefore is differential and unresponsive when equal currents pass from left to right or from right to left along both of the wires of the symbol; but when either wire carries a current and the other wire does not, the ringer will be responsive, and when the two wires carry currents which flow in opposite directions as they traverse the symbol the effect will be cumulative and each current will strengthen the effect of the other.

This principle may be applied in reading symbols of induction coils, such as those of Figs. 36 to 56, inclusive. The interpretation of current values in coils of the inductoriums there shown may be expressed in the following rule: An increasing current flowing downward or to the right in any winding will produce by induction a current flowing upward or to the left in any and all associated windings. A decreasing current flowing downward or to the right in any winding will produce by induction a current flowing downward or to the right in any and all associated windings. This is the *general rule* to which all symbols of inductive relations *should conform.* Where the direction of turns about the core is shown, the inductive relation of the windings may be determined definitely. Where the

direction is not shown, and where the above rule does not fit, it is merely a case of a symbol drawn by a draftsman who had either a rule of his own or no rule at all. The reader of a circuit diagram has as his task the reading of the diagram as it has been made, not as it should have been made.

Simple condensers are typified in Figs. 502 to 505, inclusive, giving the symbols for electrostatic capacity.



Figs. 502 to 510. Symbols for Condensers, Simple and Adjustable, and for the Artificial Line.

The symbol of Fig. 505 manifestly is drawn to represent a rolled condenser. Comparing this symbol with Fig. 482, it will be noticed that the sole difference lies in the joining of the inner ends of the lines which in the one case represents the conducting wires of a helix and in the other represents the edges of the conducting sheets of the condenser.

Relative dimension of condensers is shown in the comparison of the symbols of Figs. 503 and 504; more leaves, rather than a longer leaf, is the key to the distinction.

Adjustable condensers are shown in Figs. 506 and 507. By the plug switch of Fig. 506, one or more of the condensers in the middle of the symbol may be connected across the leading-in wires at the left of the symbol. In Fig. 507, the condensers are permanently joined at one side to one of the leading-in conductors, and each has a switch whose mechanical structure is not disclosed by the symbol, by means of which any or all of the condensers may be connected across to the other leading-in conductor. An adjustable value of capacity thus is afforded.

An electric line of metallic circuit and having the features of distributed resistance and distributed capacity is symbolized in Fig. 508. Such a symbol usually is called the symbol of an artificial line, the physical line of a diagram being represented usually by an unbroken line, in accordance with the symbols for conductors.

Figs. 509 and 510 show symbols for an adjustable artificial line. In these symbols, the resistance and capacity are not distributed as in Fig. 508.

The symbol for an artificial line will be encountered in circuits wherein differential or balanced apparatus is included and wherein it is necessary that some local circuit carry a current at all times equal to the current passing over the transmission line. In such an instance, an artificial line, preferably adjustable in the symbol, is included in the local circuit, and this artificial line is adjusted to have approximately the same resistance and capacity as the physical line over which the transmission is being effected. Re-

peater and composite circuits sometimes use the artificial line.

In its simplest form, the symbol for the artificial line becomes merely a resistance symbol and a condenser symbol in multiple.

LESSON XXI.

CONDUCTORS. CURRENTS. CODED CONDUCTORS. LABELS.

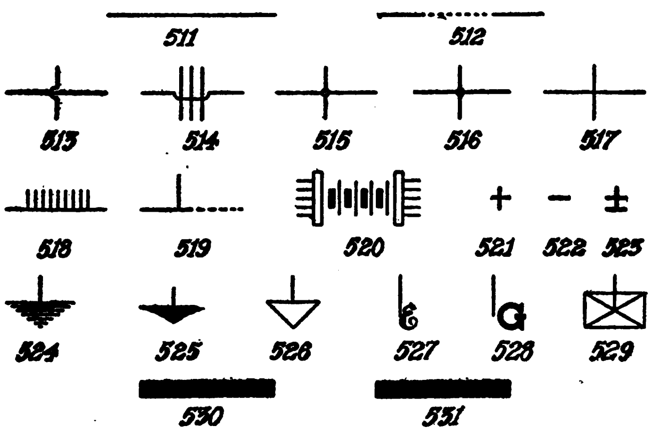
An electrical conductor is represented in a diagram usually by an unbroken line joining the points of apparatus between which the conductor extends. See Fig. 511. This symbol for representing a conductor does not suggest the material from which the conductor is made, nor the distance between the points represented at the ends of the conductor, and which are joined by the conductor.

A conductor seemingly very short in a diagram may be of considerable length when the wiring of the actual apparatus is studied. To suggest length, the symbol of Fig. 511 is modified as shown in Fig. 512, wherein the dotted portion of the line indicates distance. Such a broken portion usually is found in conductors leading from a central office to a substation, or in conductors leading from symbols for equipment located in one central office to symbols for equipment located in another central office.

As conductors are drawn in a diagram, it becomes necessary to cross them in many places; hence a convention has been adopted to indicate that two wires which cross are not connected electrically. This convention is the half-circle jump of Fig. 513. When a group of wires is to be crossed, the jumping wire sometimes is drawn in a single displacement to cross all of the group, as shown in Fig. 514. This renders

the conductor which jumps more easily read, but the conductors which are jumped, particularly in the middle of the group, do not show so clearly when they are being traced that the crossing wire is a jumping wire.

When conductors are electrically joined, a small circle or a solid black dot is used; this might be thought of as the symbol for a soldered joint. A



Figs. 511 to 531. Symbols for Conductors.

branching wire, as in Fig. 519, is clearly a case of electrical joining; the dot or circle symbol of Fig. 515 or 516 usually is used, and is not out of place.

Where wires cross without any indication, as in Fig. 517, the diagram must be studied to determine the draftsman's rule. Perhaps he is using the symbol of Fig. 513 but not of Figs. 515 and 516; perhaps he is

using a symbol of Figs. 515 or 516 but not that of Fig. 513. (See Fig. 532.)

A wire which branches to many points is called a 'bus wire, sometimes written bus wire or improperly buss wire, an abbreviation of "omnibus" wire, or wire for all purposes. The symbolization of such wires is shown in Figs. 518 to 529. The heavy battery terminals symbolized in Fig. 520 are called 'bus bars, rather than 'bus wires.

In lieu the symbol of Fig. 520, or in any source of current or constant potential, the 'bus wires or 'bus bars connecting to either terminal may be indicated by the sign indicating the polarity of the terminal to which they connect. Thus, in a diagram where a battery and a ringing generator is shown, the symbol of 521 adjacent to the terminal of a wire indicates that the wire extends to the positive terminal of the battery; that is, the symbol of Fig. 521 may be interpreted as a symbol for a 'bus conductor. Likewise, the symbol of Fig. 522 is the symbol of the 'bus conductor connected to the negative terminal of the battery, and the symbol of Fig. 523 is the symbol of the 'bus wire of the alternating-current source, or ringing generator. The earth conductor is indicated by symbols in similar manner, some of the symbols used being given in Figs. 524 to 529, inclusive.

Fig. 524 gives the symbol most frequently used for the earth conductor. Figs. 525 and 526 are modified forms less frequently met. In Figs. 527 and 528, the *E* abbreviates the word "earth" and *G* abbreviates

the word "ground." Fig. 529 is an earth symbol which has been used much in diagrams pertaining to art of telegraphy.

Contrasting with the symbols for conducting mediums, the symbols of Figs. 530 and 531 are for insulating mediums. Fig. 531 represents section of insulation, where the section is one of considerable area in the drawing; where the section is of small area, the solid black of Fig. 530 is employed. For surface or elevation of insulation, solid black is employed except where the surface is large, in which case it is shown white.

Fig. 532 is a figure selected to show the crossing of conductors in a diagram. In the upper portion of the figure, there are several instances where one conductor crosses another without contact, and the convention of Fig. 513 is observed. In the lower portion of the figure, however, the crossing conductors form such a maze that the use of the same convention would only render the conductors more difficult to trace; hence it is abandoned and the lines are drawn straight. This figure offers also a specimen diagram for elementary practice in circuit tracing. At the left, the pairs of terminals are terminals of telephone lines, as indicated by the apparatus associated with pair No. 1. Assuming that the substation telephone is closed across the line conductors of that pair, circuit is completed through the battery, relay *r,* the line conductor, the substation (not shown in the diagram), the return line conductor, relay *R* and earth to the battery again. This energizes relays *r* and *R*. By the closing of their

armature contacts, a circuit is closed including the battery and lamps. In like manner, a closed path between any pair of terminals at the left will energize two relays and cause the corresponding lamp at the

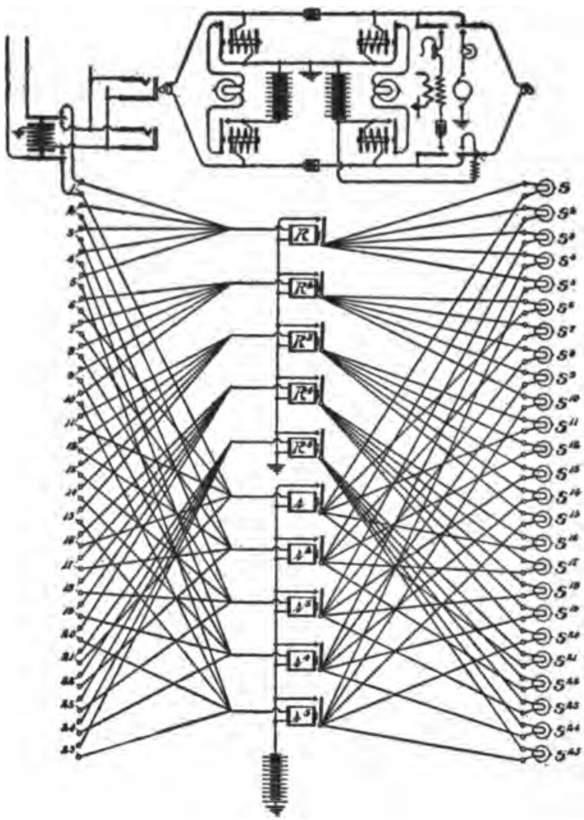


Fig. 532. Conductors in Mass.

right to glow. It is interesting also, but more difficult, to trace the current which flows through lamps other than the one which is intended to glow by an inherent defect in the theory of the circuit, and also to discover the results upon the lamps when any *two pairs* of terminals at the left are bridged at the same time, as by two telephone substations calling the switchboard at the same time.

The "coding" of conductors in a circuit diagram consists of specific modification of the conductor symbol to indicate the purpose for which the conductor is used. Figs. 533 to 536 show some codes which have been used.

Most widely used of all coded conductors is the heavy conductor for the "talking pair;" that is, for the wires which carry the speech currents of a telephone conversation. This is seen in Figs. 548 and 549. By this distinction, it is easy to follow the "talking circuit" through the diagram, and to recognize it whenever any signal wire is traced into operating relation to it. The same principle is extended to other wires, particularly in wiring diagrams.

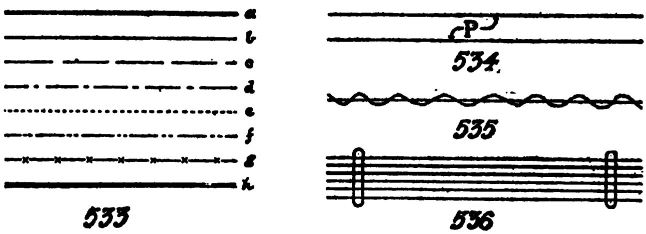
Fig. 533 shows a code of conductors to illustrate the principle, extended to conductors of several classes. While the different line values may be assigned to different classes, arbitrarily, the following list will be typical.

a—Conductors carrying speech currents of conversations between subscribers.

b—Conductors carrying signaling currents individual to a specific signal device.

c—Battery 'bus, live side or ungrounded side.
d—Battery 'bus, grounded side of battery.
e—Alternating-current, ringing leads, 'bus wires.
f—Signaling circuit, common to more than one signal.
g—Interrupted current, or pulsating current 'bus wires.
h—A derived circuit upon the speech conductors.

The above line values and their code as given are observed in Fig. 549. The code for the calling plug's



Figs. 533 to 536. Coded Conductors.

equipment sometimes differs from the code for the answering plug's corresponding equipment.

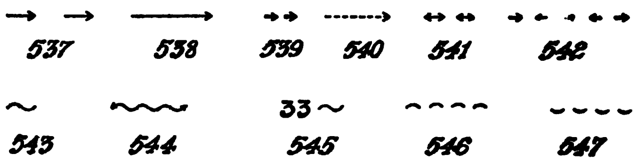
Fig. 534 shows the symbol for a twisted pair; the two wires indicated by the *P* are twisted together either in a single duplex wire or in cables. *T* may be found instead of *P* or sometimes *TP*. The symbol of Fig. 535 also indicates that the two conductors are a twisted pair and insulated from each other.

In Fig. 536 the symbol is the loop surrounding the group of parallel conductors. This indicates that the

conductors enclosed within the loop form a cable in the wiring of the apparatus.

A flow of current, without any showing of the absolute value of the current, has been indicated by arrows placed near the conductor. For discrimination between currents, either simultaneous or at different times, the arrows vary in size and shape. Arrows for alternating currents either point in both directions or are curved.

Figs. 537 to 540 are symbols indicating that direct current flows in an adjacent conductor; the arrow heads sometimes are found drawn upon the conductor



Figs. 587 to 547. Symbols Indicating Currents.

instead of adjacent thereto. Figs. 541 to 545 are symbols for alternating current in an adjacent conductor. The arrow points are omitted from the symbol of Fig. 543, and in Fig. 545 the frequency is indicated by the figures, the current value being not shown. Speech currents are indicated by the alternating current symbols. Figs. 546 and 547 are suggested symbols for pulsating current, positive and negative, respectively.

That the different parts of a drawing or diagram may be referred to definitely, identifying the part without possibility of error, labels sometimes are placed upon the drawing adjacent to the different

parts. These labels may consist of complete words, or of abbreviations, letters or figures. Usually a "leading line" extends from the label to the particular

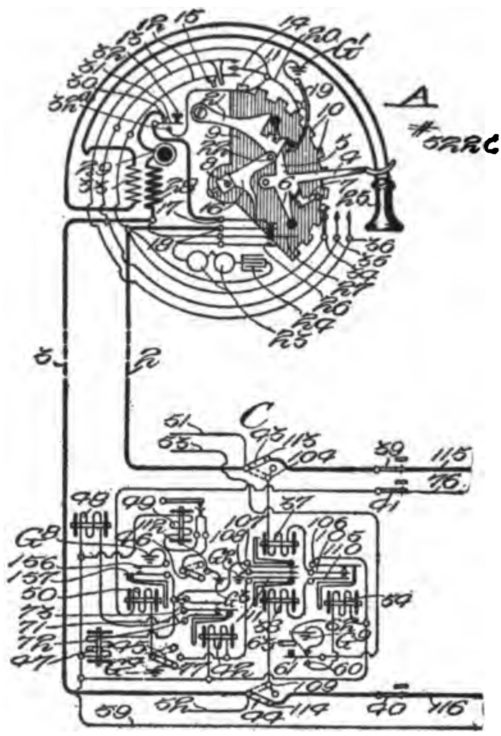


Fig. 548. Patent Office Labels.

conductor or apparatus part to which the label pertains. This system of labels is common wherever a written description accompanies the drawing or dia-

gram, and is universal in patent office drawings. Fig. 548 is an excerpt taken as a horrible example from a patent in which the principle of labeling the diagrams was carried to absurdity.

LESSON XXII.

SKELETON CIRCUIT AND WIRING DIAGRAM.

Two related diagrams of the two classes, wiring diagram and skeleton circuit, are shown in Fig. 549. The lower part of this figure presents a detailed diagram for the wiring of a pair of plugs upon a common battery switchboard of a specific type. Accompanying the wiring diagram, at the top of the figure, is the related skeleton, covering the same subject as the detailed diagram, and offering at the same time both a simplified view of the circuits and an explanation of some details of apparatus parts not shown in the larger drawing.

From the skeleton diagram it is seen at a glance that the two plugs are connected through a repeating coil which feeds current to the talking conductors; that a double-action key rings upon the calling plug or permits the operator to listen upon the pair; that mechanical visual signals controlled by relays are used and that they are displayed continuously while current is flowing to the talking conductors; that the bodies of both of the plugs are connected to the main battery, presumably for busy test purposes.

The wiring diagram shows that the answering plug is behind or "back" of the calling plug; that each plug is connected by a flexible cord to a set of three terminals, marked *T, R, S;* that in the connecting rack of the switchboard where the cords are at-

tached the tip terminal is top, the ring terminal is middle and the sleeve terminal is at the bottom of the set of three. It shows that the two supervisory relays are mounted one above the other, the answering-plug relay being the upper one; also that the two signals are similarly mounted and related; probably also the signals are higher in the switchboard frame than the relays. It shows also many fuse mounts and fuses which are not indicated in the skeleton, and many terminals. The terminals are accompanied by labels indicating their use, and those labels probably would be found stamped in the switchboard adjacent to the respective terminals; this is true also of the labels adjacent to the fuse mounts, and upon the relays, and signals.

Many details of the wiring of the switchboard are disclosed very definitely when the coding and branching of the conductors are studied carefully.

The talking wires of the figure are all individual to the pair of plugs shown, there being of course other pairs, in each of which the talking wires are individual to the pair, no talking wire being common to any two pairs of plugs. These wires are drawn heavy, according to code *a* of Fig. 533. The respective terminals of the repeating coil, at the lower edge of the diagram, are identified upon the physical apparatus by the locations of the terminals, and the same is true of the relays and key terminals. The view in the wiring diagram of the relays *A* and *C* is taken such that the terminals are fully identifiable; the remaining characteristics of the relays are unimportant to the matter

of installing or supervising the connecting wiring. The function of the relay is left to the skeleton diagram.

The battery connection for the repeating coils extends from the terminal *B* by a single wire in *c* code to the fuse of the cord pair illustrated, thence onward to other similar fuse mounts, as is indicated by the *c* code line branching downward from the left end of the fuse. The fuse is connected to the repeating coil terminal by a *b* code line, indicating that the connecting wire and therefore the fuse itself is individual to the repeating coil, and not common to two or more repeating coils.

The ground connection to the repeating coils extends from terminal *BG* (probably "battery ground") to the repeating coil terminal and then branches downward in *d* code line to other similar terminals.

The fuses *T* (test), *L* (line signals), *S* (supervisory signals), *O* (operator's telephone current supply), and *A* (alarm circuit) are connected to the *B* battery terminal by a wire other than that which leads to the repeating coil fuses.

From the test fuse *T* leads a 'bus wire in *f* code to a terminal of the resistance coil labeled *R* and then continuing to other similar coils, as indicated by the branch wire still in *f* code. From each of the resistance coils an individual signal wire (*b* code) leads first to the sleeve terminal of the answering plug, then to the sleeve terminal of the front or calling plug. The wiring diagram shows clearly therefore that each plug pair has its own resistance coil for test.

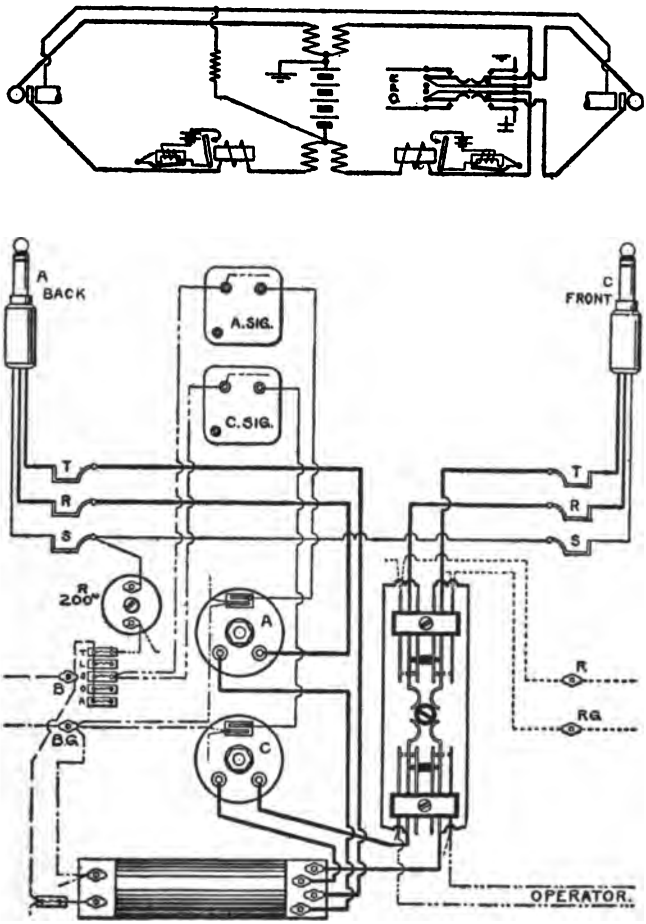


Fig. 549. Wiring Diagram, with Skeleton.

From the fuse *S* two 'bus signal wires (*f* code) extend to the answering and calling signals, respectively, each serving all of the answering and all of the calling signals of the switchboard, respectively. This is shown by the branch wires in *f* code which lead to the right from the terminals of the signals illustrated.

In the relays *A* and *C*, for some reason known only to the maker of the diagram, it is instructed by the diagram that a 'bus wire from the terminal *BG* serve all of the *A* relay contacts and a similar but separate wire serves all the *C* relay contacts. As there is no interposed apparatus, these wires are drawn in *d* code. It would seem that *f* code would have been appropriate.

The *A* relay contact is connected to the *A* signal by an individual signal wire (*b* code); the same is true of the *C* relay contacts and the *C* signal.

The ringing 'bus wires (*e* code) are brought from the power board to the terminals *R* and *RG*. Thence, the pair is taken to the indicated terminals of the key illustrated and then to the analogous terminals of similar keys, as indicated by the branching wires (*e* code) leading to the left.

The operator's circuit, in the lower corner at the right, is drawn in *f* code, indicating a common signaling circuit. While these wires carry speech currents, they do not carry speech currents between subscribers in conversation. For this distinction, they are drawn in *f* code rather than in *a* code. The operator's circuit also passes from key to key, as indicated by the branching wires at the terminals of the key illustrated.

The wires from terminals *B* and *BG* to the left and to the power board, and from terminals *R* and *RG* to the right and to the power board, will be found in detail in the power plant wiring diagram.

The wires connecting to the line-signal fuse *L* will be found in detail in the wiring diagram of the line circuit.

The extension of the circuit marked *Operator* will be found on the wiring diagram of the operator's circuit, in which circuit diagram will appear also the fuse *O* and its proper connections.

The fuse *A* and the unconnected terminals of the signals *A* and *C* will be found provided for fully in the wiring diagram for alarm circuits.

It is possible that for some switchboards all the circuits of the switchboard may be represented in a simple complex wiring diagram, but the separation of the wiring diagram into parts as indicated above is the form most likely to be encountered.

LESSON XXIII

PHANTOM CIRCUITS.

"The phantom circuit" is the name given to a derived circuit upon a telephone line, the system of connection of the principal and derived circuits and of the instruments working upon them being such that the instruments of the principal circuit are unresponsive to currents flowing over the derived circuit, and the instruments of the derived circuit are unresponsive to currents flowing over the principal circuit. The two circuits are operatively independent.

The phantom in one of its forms may be understood from Fig. 552 and the circuit of the Wheatstone bridge. The Wheatstone bridge formed the subject of Fig. 445. When a Wheatstone bridge is adjusted to a balance, the galvanometer is unresponsive to currents through the battery circuit; a dozen galvanometers might be connected between the two detector terminals of the bridge, and the wires between the two ends might be indefinitely lengthened, yet this would be true. In Fig. 552, such a distorted or modified Wheatstone bridge arrangement is shown. The ratio arms are at the left, the battery circuit entering at the middle; the resistance arms are at the right, with the battery circuit leaving at the middle. Telephones connected between the pair of line wires of this form of Wheatstone bridge arrangement would correspond to galvanometers across a balanced Wheatstone bridge

and will be unresponsive to any currents passing over the battery circuit. By converting the battery circuit of the bridge arrangement into a telephone line by connecting telephones between its ends and earth, there will be constructed a derived or "phantom" telephone circuit consisting of the two line wires in parallel and an earth return. The telephones upon the main telephone circuit will be unresponsive to the speech or ringing currents of the phantom line. Also, by a study of simultaneous potentials, it may be shown that the telephones of the phantom circuit are unresponsive to the speech or ringing currents of the principal telephone line upon which the phantom is derived.

For convenient discrimination, the terms "phantom circuit" and "physical circuit" are used, the physical circuit being that circuit using a pair of wires in series for the transmission of currents, and the phantom circuit being the derived circuit which uses the pair in parallel.

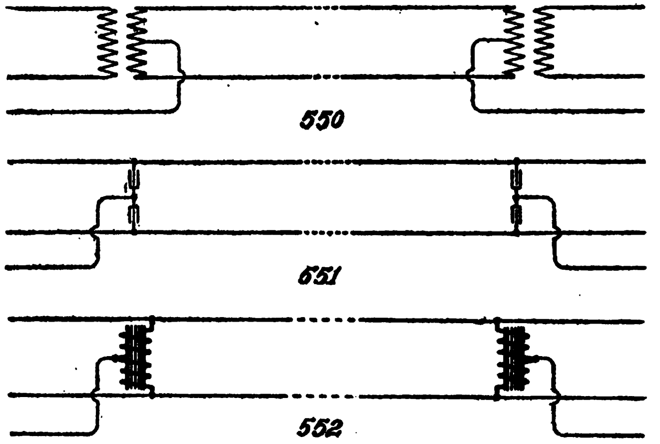
There is no symbol for the phantom, *per se*. It is a circuit, traced through such symbols as may be required to represent the apparatus required to set up the phantom condition in the diagram.

Fig. 550 shows a diagram of a phantom formed with repeating coils. This is the easiest and most convenient form to construct and use in service, and therefore most likely to be met in circuit diagrams.

Fig. 551 shows a diagram of a phantom formed with condensers. The condensers used are of small capacity. The condenser phantom may be used for

telephone service only, because only fluctuating currents may be transmitted over it.

Fig. 552 shows a diagram of a phantom formed with retardation coils. For currents which flow from wire to wire of the physical pair, the retardation coils are highly inductive; for the currents of the phantom circuit, which flow between the center and both ends, the retardation coils are neutral or non-inductive, thus presenting only their ohmic resistance.

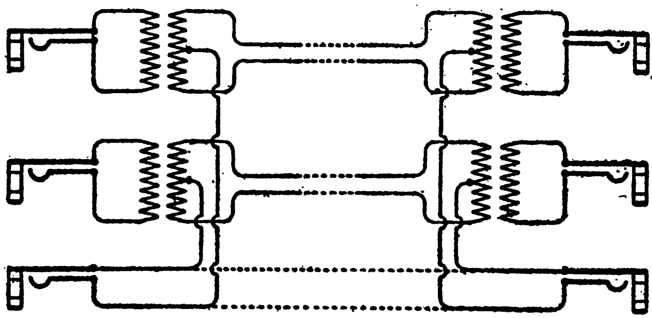


Figs. 550 to 552. Phantom Conductors.

In each of the three instances, the currents of the phantom circuit divide in the bridging phantoming apparatus and flow equally upon the two wires of the physical circuit.

Figs. 553 to 557, inclusive, show some applications of the phantom circuit to practice in telephony, as likely to be met in telephone circuit diagrams.

Fig. 553 shows two physical circuits connected as two trunks between two switchboards. The derived circuits of the two physical circuits are used to form a metallic circuit phantom, being the equivalent for



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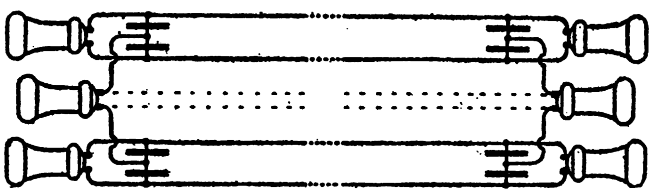

554

Figs. 553 and 554. Metallic Circuit Phantom Telephone Lines.

commercial purposes of the dotted conductors suggested at the bottom of the figure.

In Fig. 554 a similar combination of two condenser phantoms to form a metallic circuit phantom is shown, the phantom circuit produced being the equivalent of the pair of conductors suggested by the dotted lines across the middle of the figure.

In Fig. 555, telephone and telegraph circuits are shown working simultaneously over a single pair of wires, the telephone circuit being a metallic circuit and the telegraph circuit being a grounded or earth return circuit. The telephone circuit of course may pass to switchboard line or trunk jacks instead of to telephone substation equipments as indicated in the diagram. The telegraph circuits need not be on the same premises with the telephone equipment of the line, being

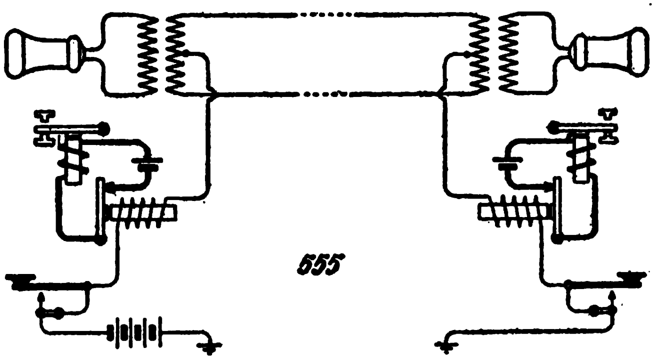

Fig. 555. A Phantom Telegraph Circuit Over a Telephone Line.

extended further to any distance desired by means of telegraphic line wires.

Physical circuits may be "phantomed" for a portion of their length, and phantom circuits likewise may be phantom for a portion of their length and physical for the remaining portion. In the switchboards, physical and phantom circuits may be connected indiscriminately.

Fig. 556 shows a telephone trunk circuit between

two switchboards in which the lamp signals are operated over the phantom of the trunk. At each end there is shown a jack, a repeating coil, a key, a lamp and a battery, the two batteries normally being connected to the phantom in opposition. The depression of the key at either end of the trunk will operate the lamp at the distant end until the distant key is operated also or the home key restored.

In Fig. 557 a circuit is shown in which the phantom of a subscriber's line is used as a circuit for sup-

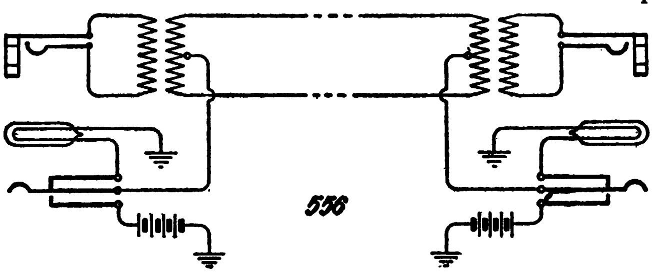

Fig. 556. A Signal Circuit Working Over the Phantom of a Telephone Line.

plying his transmitter at the substation with current from the central office battery. The battery supply circuit is traced from earth through the battery, through the right-hand relay to the middle of the line side of the repeating coil, thence over the "phantom," or both wires of the line in parallel, to the secondary of the induction coil of the substation telephone; thence through the two windings of the receiver to the hook switch and to the upper junction point in the primary circuit of the telephone, through the primary winding of the induction coil and the transmitter to

earth. The substation condenser is charged by the potential difference across the primary and transmitter, and its charge varies with the resistance of the transmitter. Variations in the volume of charge in the condenser are obtained by direct charge over the phantom of the line and by discharge through the primary of the induction coil. These fluctuating currents through the primary cause induced currents in the secondary, which induced currents are transmitted over the two wires of the "physical" line and through the repeating coil at the central office to the jacks of the central office switchboard, the energy thus transmitted over the physical circuit being non-interfering with the steady feed of current over the phantom.

In the line side of the central office repeating coil, the windings are inductive to the speech currents, but non-inductive to the currents of the phantom; in the secondary of the induction coil at the telephone, the same is true. In the receiver of the substation, which is shown wound with two coils, the same also is true. The ringer bridge is unaffected by the direct currents of the phantom, and does not require a condenser.

The central office signaling and switching circuits of this diagram will offer practice in reading eccentric systems.

When the line relay is energized by current over the phantom as above described, the path being closed when the hook lever rises and closes its contacts, current is permitted through the armature and contact of the line relay at the right, armature and back contact

of the cut-off relay at the left and signal lamp to earth, causing the lamp to glow as a signal to the switchboard operator. The potential of the battery passes also through the winding of the cut-off relay and one winding of the repeating coil to the multiple jacks, causing the line to test "busy" as soon as the receiver is lifted at the substation.

When the operator answers with a plug of the pair shown at the top of the figure, path is completed to earth for current through the cut-off relay and the

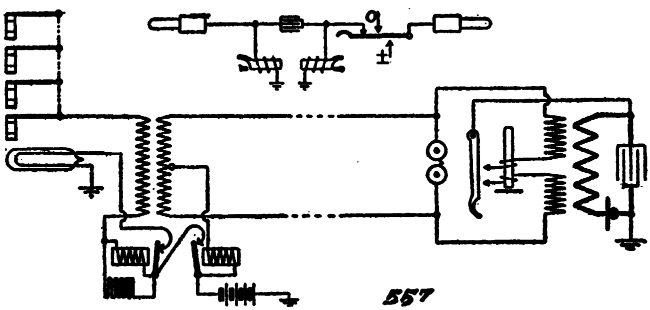

Fig. 557. A Common Battery Transmitter Fed Over the Phantom of the Telephone Line.

visual signal of the plug, energizing both, interrupting the current of the lamp by opening the contact of the cut-off relay, and continuing the display of the visual of the plug so long as the receiver remains off the hook at the sub-station.

But one wire passes from the line equipment to the switchboard jacks, and but one conductor is attached to the switching plugs, giving a jack and plug of maximum simplicity.

The talking circuit through the switchboard extends from the live side of the main battery through the armature and contact of the line relay, helix and non-inductive shunt of the cut-off relay, central office side of the repeating coil of the calling line, switchboard jack, plug, connecting conductors including condenser and key, remaining plug, jack of the called line, central office side of the repeating coil of the called line, helix and non-inductive shunt of the cut-off relay of the called line, contact and armature of the line relay of the called line to the live side of the main battery, which is the point at which the tracing of the circuit was begun. Prior to the answering of the called station, the circuit for ringing current extends from the cut-off relay helix to earth through the line lamp, the ringing current being repeated into the called line by the action of the repeating coil.

The key of the plug pair also exhibits a peculiarity When the moving spring is pressed upward as directions are shown in the diagram, it engages the contact *O* leading to the operator's telephone, but without breaking the contact leading to the answering plug at the left. When the moving spring is pressed downward, it breaks the contact leading to the answering plug and connects the ringing plug at the right to the contact which, according to the symbol adjacent, is connected to a source of alternating current, namely, the ringing generator.

CHAPTER XXIV

COMPOSITE CIRCUITS.

A system of composite, or simultaneous telephony and telegraphy over the same circuit, is shown in Fig. 558.

In reading this circuit, it is necessary to keep in mind the electrical constants of the various parts of apparatus. There is no new symbol for any part of the apparatus involved in this circuit diagram, but there is involved a principle which is met in nearly all telephone circuits. This is the division of currents unequally among derived paths.

By derived paths is meant the paths of a pair or more of paths, each of which will take a portion of current which at some point flows over a common path. Where constant potentials only are to be considered as sources of current, the derived paths will take currents inversely proportional to their resistances, the flow through each item of resistance being governed by Ohm's law.

Where currents of varying frequency are involved, particularly where telephone speech currents are involved, and where the paths have inductance, the currents in the derived paths do not flow according to Ohm's law. Where telephone speech currents and constant potential currents, as from a battery, flow at the same time over the same wire and then encounter a set of branching circuits, it is not at all an obvious

conclusion that they will divide into the derived circuits in the same proportions for each of the possible paths.

Such a division may not be taken for granted until after each of the possible paths has been examined for evidence of its electrical constants, viz., resistance, inductance, potential and capacity. It may be that, of a pair of branches leading from a main line wire, one of the branches will take the lion's share of the speech currents of the line and the other branch will take the lion's share of the battery currents of the line, although the one line conductor has been carrying both kinds of current harmoniously up to the point of branching.

Inductance connected in series in a conductor opposes the passage of telephone voice currents with far greater effectiveness than it opposes the passage of currents from a source of constant potential, or such currents as the intermittent currents of a telegraph system. On the other hand, a condenser connected in series in a conductor will oppose the battery currents of telegraphy most effectively, and will oppose the telephone speech currents with but little effect.

By taking advantage of these characteristics it is possible to construct a pair of derived paths, in series with a line circuit, or among line conductors, such that one of the paths will carry substantially nothing but telegraph currents and the other path will carry substantially nothing but telephone currents. Such a system renders possible simultaneous telegraphy and

telephony over the same line conductors, and it bears the name of composite telegraphy and telephony.

Fig. 558 shows a circuit diagram of a composited line. The line conductors *V* and *W* branch at the points *13* and *17* at the left and *14* and *16* at the right.

The telegraph circuits may be traced easily. Beginning at the upper left-hand corner of the diagram, at earth symbol *Z*, proceeding through battery *h*, key *n*, telegraph relay *r*, conductor *9*, and inductance or highly inductive resistance *f* to the junction point *13*, we may trace to the left from the junction point until the condenser *x* is encountered; as current from the battery *h* cannot flow through the condenser *x* which has been encountered, all current from the battery *h* must flow from the junction point *13* to the right and over the line conductor *V* to the junction point *14*. From the junction point *14* to the right and downward a condenser *x* is encountered, stopping the battery current, so all battery current coming over the line wire *V* must follow the branch path upward and to the right from junction *14*, through inductance *f*, conductor *8*, telegraph relay *r*, key *n* and battery h^2 to earth at symbol *Z*. Note that the two batteries which are included in this circuit, namely, battery *h* and battery h^2, are indicated as having grounded their poles of opposing polarity, so that the potentials of the two batteries are added in producing a current in the line conductor. The telegraph current does not flow through the condenser *i* from conductor *8* to earth, nor through consenser *i* from conductor *9* to earth.

In like manner, the telegraph circuit over line

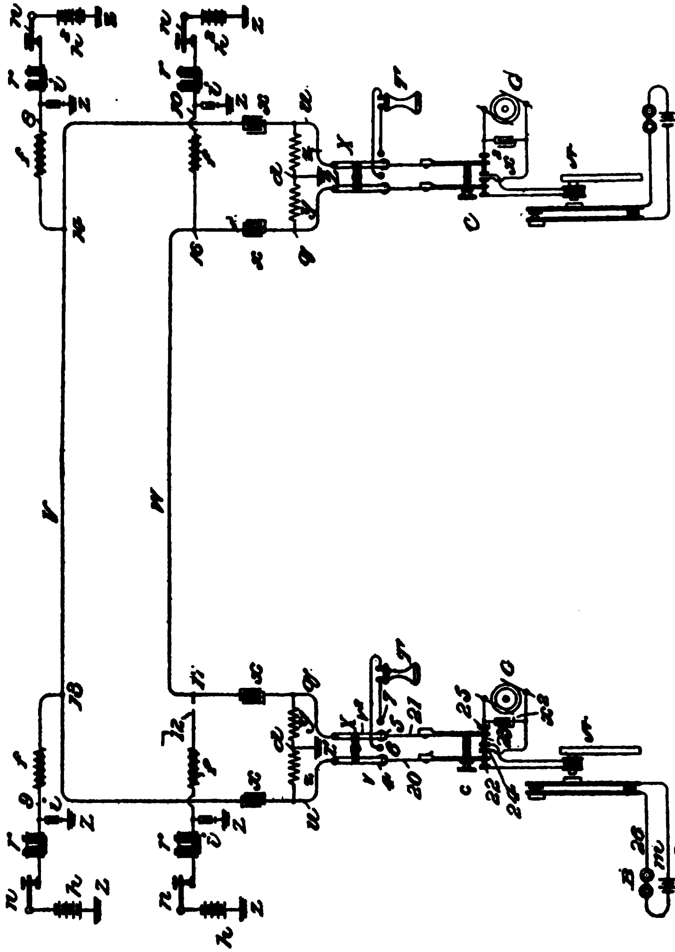

Fig. 558. Composite Circuit.

conductor *W* may be traced from earth at the left over the elements *h, n, r, f, 12, 17, W, 16, f, 10, r, n,* h^2 to earth. In this circuit also the branches to the condensers *x, x, i* and *i* are encountered, but none of these branches can carry current from the batteries *h* or h^2.

The two telegraph circuits traced are independent of each other, and may operate simultaneously and without interference.

Tracing now the path for speech currents, these must originate in one telephone *T* and terminate in the other telephone *T*, each of the symbols *T* and *T* being taken to represent a complete talking equipment. With the switches *X* and *X* at left and right, both considered as with their levers shifted to the right, the two telephones *T* and *T* are connected to the line conductors *W* and *V*.

Starting from the telephone *T* at the left, trace both conductors of the line at the same time. Passing through both levers of the switch or key *X*, and over conductors *u* and *q*, junction points are encountered which offer paths through resistances *z* and *y* to earth. While the symbols of these resistances do not specifically indicate that they are of high inductance, it seems necessary to assume that they are such, and that there is no appreciable leakage of the telephone voice currents through them, either from wire to wire of the line or to earth.

Next, the two condensers *x* and *x* are encountered, but these offer no opposition to the passage of the speech currents. When the junction points *13* and *17* are reached in the two-line wires, two more branch

paths to earth are encountered, but the formidable inductances *f* and *f* tell the defeat of any currents attempting to flow over those branches.

Substantially the total quantity of speech current output of the telephone *T* at the left therefore reaches the line conductors *V* and *W* and passes over those line conductors to the apparatus indicated at the right of the circuit diagram. Here, again, are encountered, first, the earth branches containing the blockading inductances *f* and *f*, then the friendly condensers *x* and *x*, then the ineffective resistances *y* and *z*, then the switch *X* and the telephone *T*.

The telephone current has been unable to flow through the telegraph instruments, either effectively or wastefully; nor have the telegraph currents been able to flow through the telephone circuits. The two telegraph circuits and the one telephone circuit are operating harmoniously and without interference, simultaneously, upon the single pair of line wires *V* and *W*.

The efficiency of the condensers and inductances in shutting out the telegraph and telephone currents, respectively, is not so great but that some little leakage occurs. For this reason the small condensers *i i i i* permit to waste to earth such telephone currents as leak through the inductances *f f f f*, and the inductances *z y y z* permit to waste to earth such telegraph energy as may leak through the consensers *x x x x*.

In this circuit, ringing upon the telephone pair with a ringing generator of slow pulsations might send such heavy currents over the line conductors as

would rattle the telegraph relays in an objectionable manner. To obviate this the ringing generators *G* and *G* at left and right, for signaling over the telephone circuit of the composite line, are made of very high frequency. By the operation of either key *c* at right or left of the diagram, the current from the high-frequency generator is passed over the line conductors, and because of its high frequency it passes through the condensers and is obstructed by the inductances, as the circuit was traced for the telephone speech currents. At this time, however, when the ringing signals are being sent over the telephone line, the keys *X* and *X* are in their left-hand positions, as shown in the diagram, and the ringing current received at either end will pass down through the closed key *c* and through the helix of the relay *A*. The relay *A* formed the subject of Figs. 333 and 334, the former being a detail view and the latter a symbol. It is a relay especially designed for response to currents of high frequency, and by its action the ringing signal is announced upon the signal device *B*.

LESSON XXV

INTERCOMMUNICATING TELEPHONE SYSTEMS.

Private telephone systems may have a switchboard and be operated much as a public exchange is operated. In such instances the circuits usually are much the same.

In a small private system the switchboard may be dispensed with by some arrangement which enables each station of the system to call any other station without the assistance of a central office or switching station. This method of operating requires at each station an intercommunicating switch which will enable the subscriber there to place his telephone in connection with the line to any other station.

A simple system of this type is shown in the diagram of Fig. 559. Five lines are shown. Assuming that the system is a metallic-circuit system, each line of the diagram represents a pair of line conductors. Five stations also are shown; one telephone line for each station. At each station five switching jacks are shown—one for each of the lines. At each station a telephone set is shown, attached to a switching plug for the jacks. That portion of the telephone conductors adjacent to the plug in each station, resembling to some extent the symbol of Fig. 479, is in this instance but an indication that the switching plug is united to the telephone set by a flexible cord. In connection with the station *S* a call bell is shown; it is obvious,

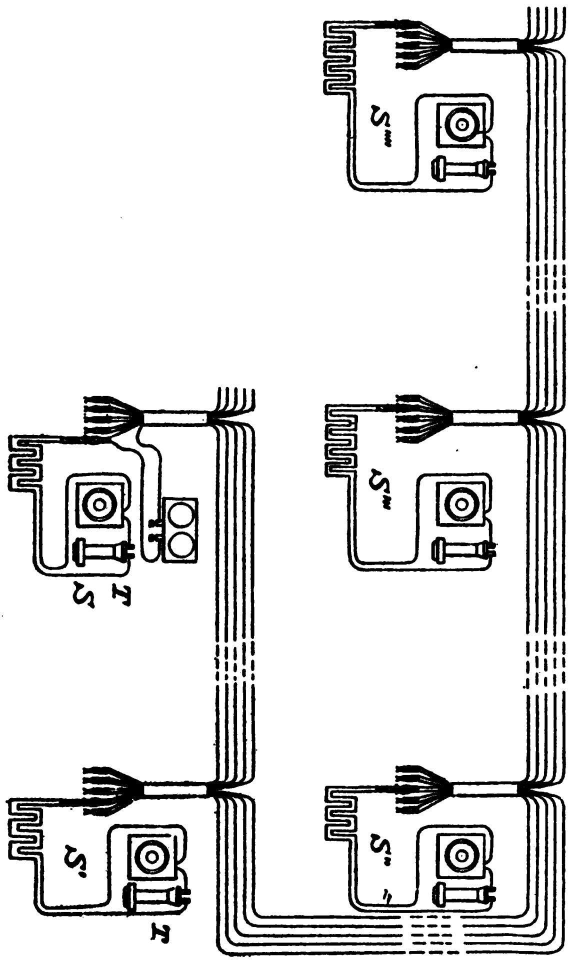

Fig. 559. Intercommunicating Circuit.

however, that each station must have some sort of calling device, either attached permanently to its own line, as the call bell of station *S* seems to be, or forming a part of the telephone set indicated as a whole by the transmitter and receiver shown at *T* for each station.

Station *S* normally, when idle, is connected by its plug and jack to that line belonging to the right-hand

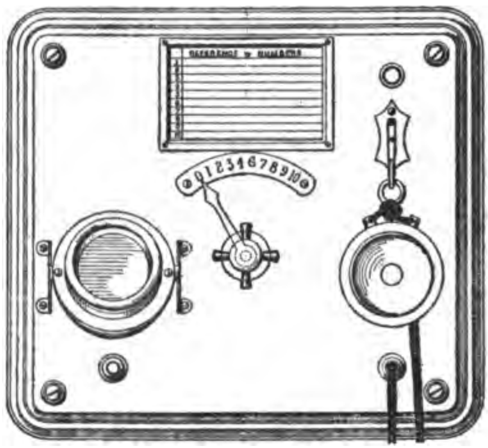

Fig. 560. Intercommunicating Switch Box, Exterior.

jack, or first jack of all of the sets of jacks. Station *S'* normally is upon the line connected with the second jack of all the sets, and similarly for stations S^2, S^3 and S^4. Each has its own line, and normally is connected through its own plug to its own line.

In operation, if any station desires to call any other, the telephone user removes his home plug from the jack of his home line and places it in the jack be-

longing to the line of the station which he desires to call. This connects both of the telephones to the one line, and assuming now that each of the telephones is equipped with call bell and generator, the first party may ring up the second and hold conversation.

Intercommunicating systems will be found to embody this principle in different forms of apparatus. Provisions for busy test of the desired line, and pro-

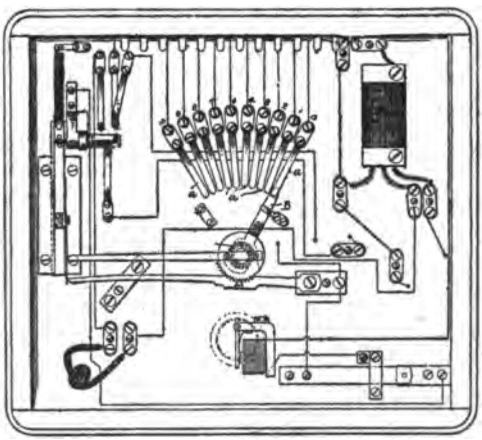

Fig. 561. Intercommunicating Switch Box, Interior.

visions for "locking out" or preventing access of a third station to a line in use by two stations in conversation may be encountered, also many specific types of switches.

As an illustration of a specific type of intercommunicating switch, a face view of the outside of the switch is shown in Fig. 560, and a view of the interior is shown in Fig. 561. Attention is directed to the

pivoted switch arm *B*, near the middle of Fig. 561, and the arc of fixed contact springs *a, a, a, a, a,* with any one of which the movable switch arm may make electrical contact.

The circuit diagram of Fig. 262 shows circuits suitable for the apparatus of Figs. 560 and 561. Two stations are shown. The lower station is calling the upper one. The condition of apparatus is that in which the lower station is ringing the signal bell of the upper station. To emphasize the ringing circuit its conductors are given a heavier line value, making them easily traced.

Ringing current is flowing from the earth symbol of the lower station, as indicated by the arrows adjacent to the conductors, as follows: *t', g', t', g', q', l', j', 6, i', z, G, x, c', B, a, L'*. The conductor *L'* is one conductor of a cable which passes to all stations, and this particular conductor is connected to all stations, to the left-hand contact point of the switch, according to the fundamental principle of intercommunicating systems as studied in connection with Fig. 559.

At the upper station of Fig. 562, which is the home station of the conductor *L,'* the circuit traced in part in the lower station of the figure is completed through *L', a, B, c', x,* h^2, *d', w, s, e', r, f', g'*, to the earth symbol.

The battery *q'* included in this circuit causes a current to flow, but the vibrating bell *r* causes the current to be pulsating or intermittent. The signal bell *r* at the upper station is rung, and the resonator *6* at the lower station vibrates its armature in response to the

pulsating current, and thus announces audibly to the calling party that he is ringing the bell of the called station.

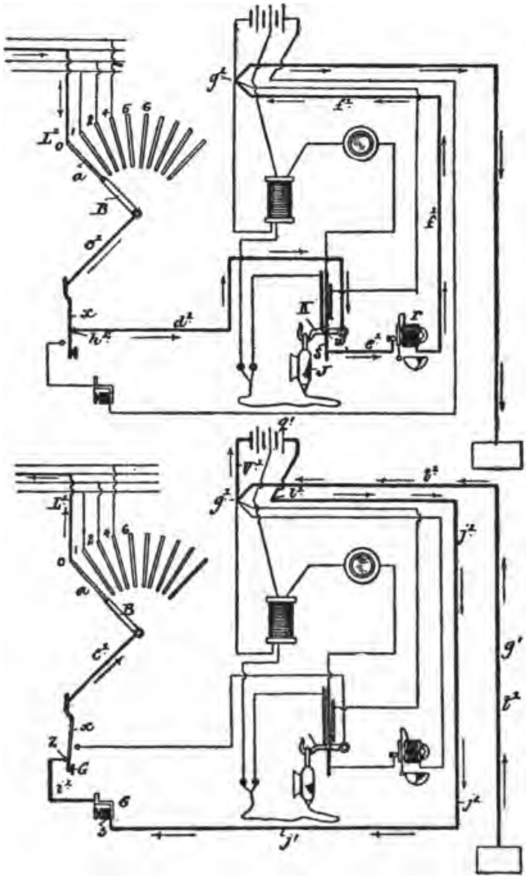

Fig. 562. Intercommunicating Circuit.

When the key *G* of the lower station is released the ringing will cease. The student then may assume that both receivers are lifted from their respective switch hooks, and the talking circuits may be traced.

LESSON XXVI

AUTOMATIC TELEPHONE SYSTEMS AND APPARATUS.

In the systems just studied each station has had its own switch at the station, and all wires have been brought to each telephone station. In the diagram of Fig. 563 a distinction is found in the placing of all of the switches at a single point or central office. In this arrangement each of the several telephone stations has its own line wire and its own selecting switch, but the switch is not located at the telephone. This renders necessary some controling devices and systems whereby the telephone station may be able to operate its switch at the central office to connect with the desired line, and later to disconnect from it. Such a system and its modifications are called automatic telephone exchanges. The central office switches are controlled by electric impulses in groups and series and over variant circuits, originated at the substation or directly controlled by the substation telephone. The central office circuits often become very complex.

In the automatic central office, the apparatus consists almost invariably of a set of movable brushes, or sets of them, passing over many sets of fixed contacts and making electrical connection with only one fixed set at any one time. In connection with the movable brushes are electromagnets for moving them or for controlling their movement, and usually a plentiful allowance of relays.

A device peculiar to the automatic central office is the pilot switch. This appears frequently as an auxiliary switch to a larger switch. The object of the pilot is to change the central office circuits which are to be controlled from the substation, in such manner that

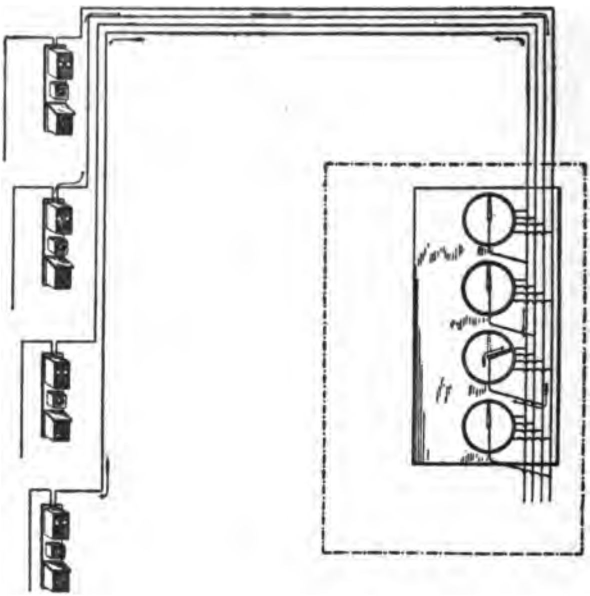

Fig. 563. Simple Theoretical Automatic Circuit.

impulses similar so far as the substation is concerned will be effective in different ways or upon different apparatus in the central office.

In one system of automatic telephone switching, the current impulses from the substation are sent over the line conductors separately, with an earth return in

each instance. This provides two entirely independent paths for the transmission of signal impulses of current from the substation telephone to the central office to control the operation of the central office switches. Of these two paths, in this system one is reserved exclusively for the operation of pilot switches.

In Fig. 564 are shown symbolically a set of movable brushes, movable over sets of fixed contact points, together with the necessary operating electromagnets.

The three movable brushes of the set are labeled *20, 21, 22*. A ratchet *A* is at the same time a means for driving the brushes into the desired position and a means for holding them in that position as long as desired. Propulsion is effected by the magnet *18* driving its armature *C* and pawl *D*. Retention is effected by the pawl *M*. At each operation of the armature *C* the ratchet *A* is propelled through an angle of one tooth and moves the brushes *20, 21, 22* from connection with one set of fixed contact points into connection with the next set.

The switch of Fig. 564 apparently has a normal position in which the conductor permanently attached to the lower end of the longer of the brushes or wipers is in electrical connection with the conductor leading to the left at the top of the diagram. Upon the first step of the brushes when propelled by the ratchet *A*, the three wipers are stepped forward and the three conductors which are attached permanently to the lower ends of the three wipers thus are brought into electrical connection with the three conductors leading to the right at the top of the diagram. By subsequent

steps, the three conductors of the three wipers are brought into connection successively with the sets of fixed contacts represented in the diagram by the sets of three small isolated circles, and with such conductors as may be connected thereto.

The object of the automatic switch, in automatic

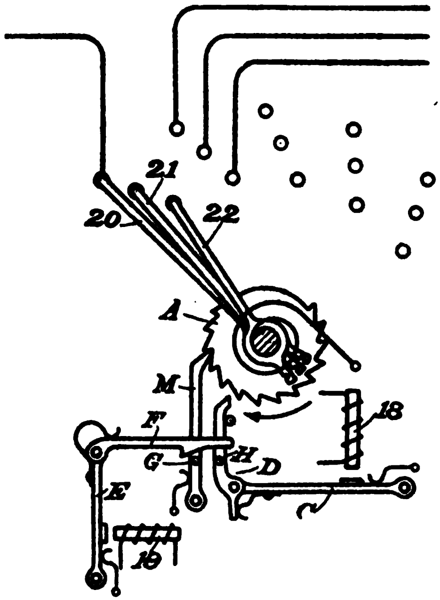

Fig. 564. Simple Automatic Switch in Symbolic Form.

telephone switching, is the selection of a desired one of a number of similar units of apparatus. Because of this general function of the automatic switch, it is to be assumed in reading a diagram that the many sets of fixed contacts with which the wipers may be brought into

connection represent each a similar set or unit of apparatus to be selected. Thus, if the three wipers leading to the right at the top of Fig. 564 are found to lead to a substation telephone set, then it is to be assumed immediately that the next set of three small circles are connected to a similar set of three wires leading to a similar telephone set, and so on for all of the sets of fixed contacts represented by three small circles per set which may be found in the symbol available for the wipers *20, 21, 22*. The selection which is the object of the switch is effected by bringing its three conductors permanently connected to its wipers into connection with the desired set of fixed contacts, whereby the conductors of the wipers are extended to the desired one of the substation telephone sets.

If the three wires leading to the right are found to pass to another selecting switch, the reader of the diagram should assume that the remaining sets of fixed contacts also connect to similar selecting switches.

The desired connection having been "set up" by propelling the wipers of the automatic switch into electrical connection with the required set of fixed contacts, and having been maintained as long as desired, it becomes necessary to release and restore the switch to its original condition.

A spiral spring may be noted upon the ratchet *A*, indicating that when the ratchet *A* is released from the pawl *M* the restoration of the wipers will be effected by the spring. The release is affected electromagnetically.

The release magnet is found as a part of most

automatic switches, although a theoretical control of the switch is possible without it. Further, it is typical of the release magnet that it effects the release and restoration of the switch mechanism not upon having its core magnetized, but upon having its core discharged. Such a magnet is embodied at *19* in the diagram of Fig. 564.

By charging the core of the magnet *19*, its armature *E* is attracted. This advances the pawl *F* until the tooth in its lower edge passes over the pin *G* upon the holding pawl *M*. When the core of the magnet *19* is discharged, the armature *E* is withdrawn from the core by a retractile spring, drawing the pawl *F* to the

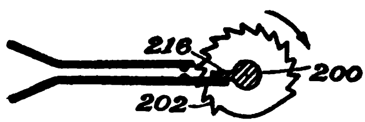

Fig. 565. An Off-Normal Switch.

left as viewed in the diagram and by pin *G* drawing also pawl *M* away from ratchet *A*. The pawl *M* is held away from ratchet *A* until the first subsequent action of the armature *C* when the pin *H* upon the pawl *D* lifts the tooth of the pawl *F* from the pin *G*.

Fig. 565 shows an "off-normal switch." An automatic switch having many positions is described as being in its "normal" position when it is in its position of rest or idleness. When in any of its many other possible positions, it is described as being "off-normal." The two-point switch in Fig. 565 holds its two contact springs separated so long as its associated automatic switch is in its "normal" position, the springs

being electrically connected so long as the automatic switch is in any one of its other possible positions, or "off-normal" positions.

In Fig. 565, the shaft *200* is the shaft which carries the wipers of the automatic switch. It is driven by the ratchet *202*. A projection *216* engages the longer of the two contact springs and forces the springs apart. At the first step of the ratchet *202*, the projection *216* moves sufficiently to release the long contact spring and to permit the two springs to make electrical contact, after which it is immaterial to the "off-normal switch" how far the shaft *200* may move to propel its wipers.

That a large number of sets of fixed contacts are accessible by the set of wipers in an automatic switch may be indicated very simply in a diagram. Fig. 548 shows in the lower portion a complete circuit for an automatic telephone switch. The set of movable brushes or wipers comprise the three brushes, *39*, *40*, *41*, which are shown in electrical connection with three fixed contacts and with the conductors attached to those contacts. Just above each of these contacts to which the conductors, *76*, *115*, *116*, are attached, are shown three isolated flat contact points, representing the contacts of another fixed set, and indicating that the brushes, *39*, *40*, *41*, have the ability to connect with any of a number of fixed sets.

In the diagram, Fig. 548, an off-normal switch is shown at *61*. The striker operating it is *63*.

The pilot of this automatic switch consists of four brushes and three sets of fixed contacts, each set of

fixed contacts comprising four contact points. The pilot switch is not shown integral, but has its parts scattered through the diagram, presumably for the simplification of the paths of the conductors leading to the pilot. The brushes of the pilot switch are labeled *43*, *44*, *45*, *46*. They are shown in full lines in their first or normal position, and in dotted lines in their third position. The set of three circles adjacent to each brush represents the three fixed contacts avail-

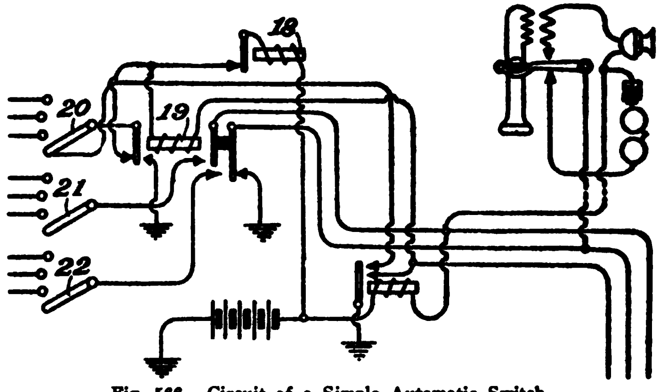

Fig. 566. Circuit of a Simple Automatic Switch.

able to that brush, one contact in each of the three sets of fixed contacts. There is a lack of uniformity in the separate parts of the pilot switch as shown, the first position of the switch being at the bottom in some of the parts and at the top elsewhere.

To read intelligently the diagram of Fig. 548, it is necessary to have a knowledge of the mechanism of the automatic switch whose circuit is shown at *C* and of the substation equipment shown at *A* as well.

The limit of the scope of the present book is to teach the principles underlying the reading of telephone circuit diagrams. Another book will treat upon the subject of automatic telephony, its principles, its theories, its mechanisms, and the detailed reading of its circuits.

In Fig. 566, banks of waiting fixed contacts are indicated by the small circles adjacent to the wipers, *20*, *21*, *22*. In this diagram it would be necessary to have

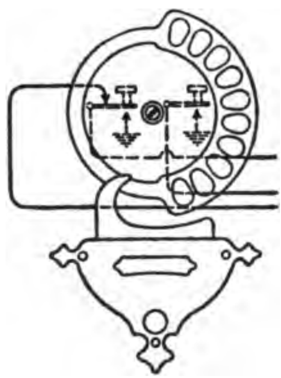

Fig. 567. Automatic Signal Transmitter.

either some knowledge of the mechanism or a considerable skill in reading automatic diagrams to determine that the magnet *18* is the motor magnet for driving the brushes, *20*, *21*, *22*, and that the relay *19* is at the same time a pilot relay and the release magnet of the automatic switch. See Fig. 564 for details of the mechanism of the switch, and compare the label numbers. The automatic switch at the left of Fig. 566 re-

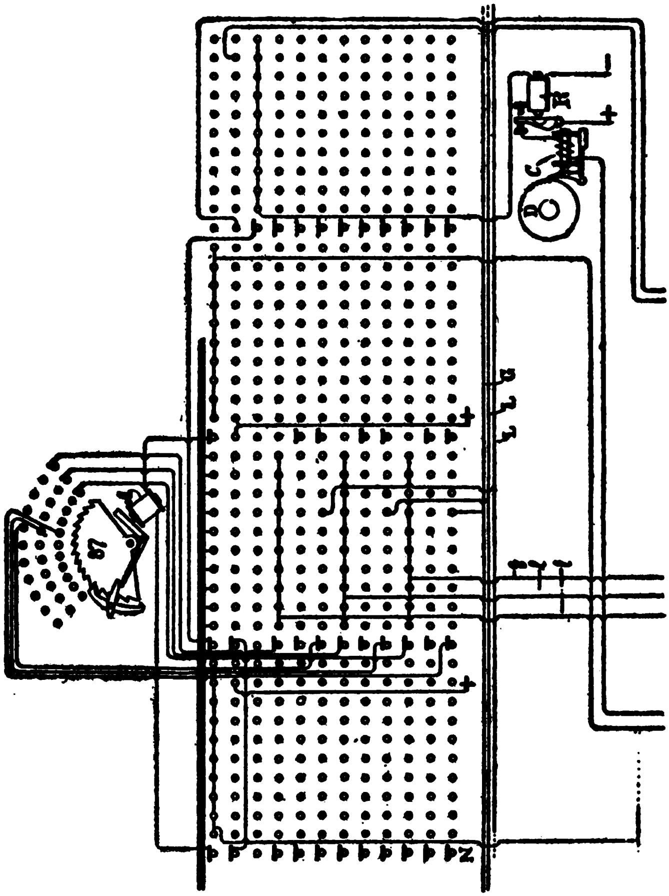

Fig. 568. Symbol for an Automatic Switch Having Two Movements of Selection.

sponds when the receiver is lifted at the substation at the right.

Fig. 567 shows a symbol for a device for transmitting impulses of current for control of automatic switches. The two telegraph keys may be operated by the large dial surrounding them. This symbol is of peculiar construction in that it embodies a front view of a calling and a circuit diagram of the device, drawn one upon the other to indicate their association.

An automatic switch is shown with all its fixed contacts in full in Fig. 568. An auxiliary switch, which in this instance is not a pilot switch, is shown at the top, at *87*. In this symbol, the fixed contacts are shown as small circles, and the brushes are shown as flat rectangles resting upon the circles. A device for controlling the movement of the brushes is shown at *C* and *D*, and itself controlled in part at least by the relay *R*. When this device controls the brushes to move, all of the thirty-nine brushes move to the right over the contact points successively. The auxiliary switch, *87*, is controlled by the magnet *A*. To connect the three wires, *l, l, g,* to the three wires, *L, L, G,* it is necessary that the brushes of the lower or large bank of contacts make seven steps toward the right and that the brushes of the upper or small bank of contacts make four steps toward the left.

A pilot switch of the same mechanical construction as the line-selecting switch of Fig. 568 is shown in Fig. 569. The brushes are paired, and number twelve pairs, each pair acting at all times to connect together two of the fixed contact points. There are

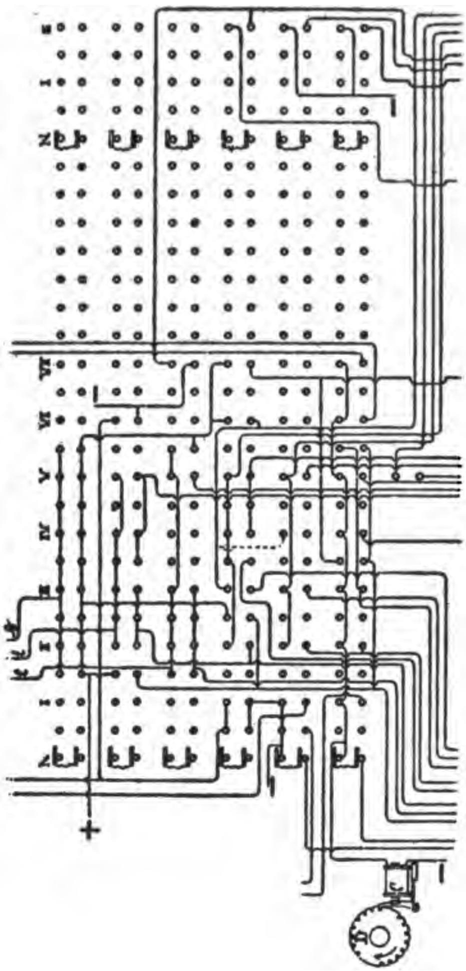

Fig. 569. A Complex Pilot Switch.

no conductors permanently connected to the brushes or wipers of this pilot switch, all wires being connected to the fixed contact points and the circuits between and among the contact points being changed by the movement of the brushes. The brush controlling mechanism shown at *C* and *D* at the left permits the brushes to stop only upon those vertical rows of fixed contacts which are numbered at the top, *N, I, II, III, IV, V, VI, VII.* It is interesting to note that the brush controlling mechanism, *C, D,* is controlled to some extent through the brushes of its own automatic switch.

LESSON XXVII

WIRELESS TELEPHONE DIAGRAMS.

In circuit diagrams of wireless telephones, the only fundamental difference in reading will be encountered in the absence of the connecting line wires and the substitution of symbols for devices for launch-

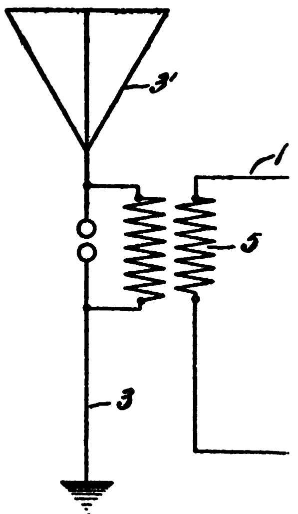

Fig. 570. Wireless Telephony.

ing the transmitted energy into space. In Fig. 570, this energy-launching apparatus takes the form of the ground wire *3* and the aerial wires or antennae *3'*. The winding *5* of the induction coil is connected to a tele-